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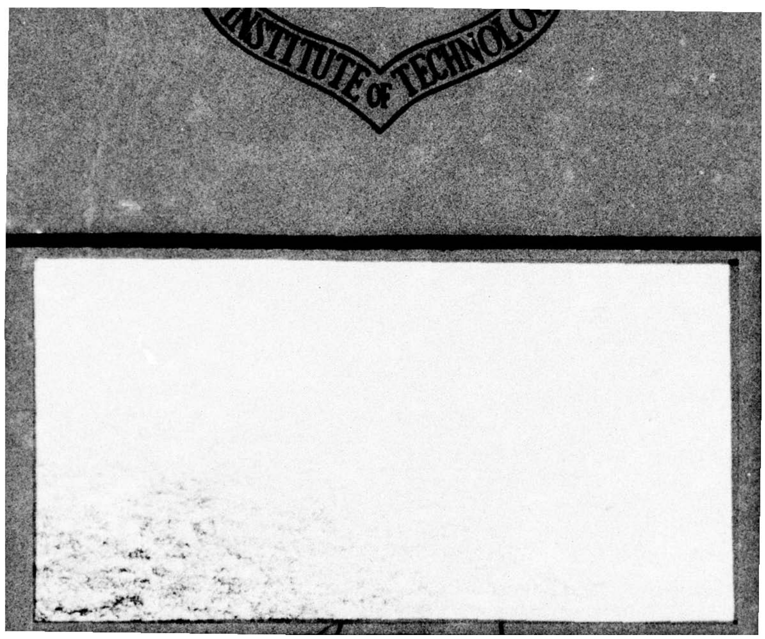
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QUANTITATIVE SCIENTIST/ENGINEER PRODUCTIVITY AND SOME ASSOCIATED INDIVIDUAL AND ORGANIZATIONAL VARIABLES.

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School of Engineering

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QUANTITATIVE SCIENTIST/ENGINEER PRODUCTIVITY AND SOME ASSOCIATED INDIVIDUAL AND ORGANIZATIONAL VARIABLES

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

by

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December 1976

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Abstract

Scientist/engineer productivity in a selected Air Force R&D laboratory was measured with the number of eight different types of output authored, prepared and/or presented, as reported by 135 scientists/engineers.

A weighting scheme was developed from the results of a questionnaire administered to 53 first level supervisors in the selected laboratory. These weights were applied to the eight output types, providing a weighted sum measure of productivity. This weighted sum was compared to the raw sum of the eight output types. The correlation between raw and weighted output was found to be, r=.985, indicating that the application of the weighting scheme only slightly changed the rank ordering of the productivity of the 135 scientists/engineers.

Through zero order and canonical correlation analyses, these productivity measures were compared to measures of 23 organizational and individual variables present in the laboratory. No single organizational or individual variable was shown to be a correlate of all eight output types. However, seven variables were significant zero order correlates of weighted output and had substantial canonical correlation loadings on joint criteria that included weighted output.

Educational level and frequency of attendance at professional society meetings were shown to be significant correlates of performance, as were variables concerning frequency of communication, both within a scientist/engineer's func-

tional section and outside it.

The degree to which a scientist/engineer participates in project and work goals was found to be a significant positive correlate of performance, as was the degree to which a scientist/engineer perceives he is rewarded for quantity of output. The length of time a scientist/engineer has under the same supervisor was found to be negatively correlated to performance.

Variables found to have little or no association with performance were age, perceived work autonomy and perceived pressures for quality/quantity of output, for meeting schedules, and for relevancy of work to the Air Force mission.

The pattern of some of the zero order correlations between the organizational/individual variables and the individual output types indicated the possible existence of broad based groupings of the eight output types.

QUANTITATIVE SCIENTIST/ENGINEER PRODUCTIVITY AND SOME ASSOCIATED INDIVIDUAL AND ORGANIZATIONAL VARIABLES

I. Introduction

Background

It is perhaps an overstatement to submit that all professional Research and Development (R&D) managers are aware of the impact of various organizational or situational variables on the performance of the scientists and engineers whom they manage. However, some managers are not only aware of this impact, but are actively engaged in programs to improve the performance of scientists/engineers under them. In 1975, Bender (Ref 7:35) reported the results of a survey of Industrial Research Institute member companies which were asked if they "did (do) have programs to stimulate creativity/productivity?" Bender did not report the total number of respondents to the survey, however nineteen companies answered the question affirmatively, identifying 44 different programs. This seems to indicate the effort that managers are taking to provide an organizational environment conducive to research productivity. The fact that a large variety of programs have been implemented may also point out that a "best" method to stimulate productivity does not exist, but varies instead from one organization to the next, partially based on which factors or organizational variables are controllable by the manager.

In the past fifteen years, there have been a number of empirical studies conducted, attempting to determine the organizational factors or variables that impact the productivity of the individual scientist/engineer. Martino (1973) reported 87 such empirical studies and postulations in which 13 various measures of scientific performance and 53 associated individual and organizational characteristics were investigated (Ref 12:72). Many of these studies investigated similar variables and related them to similar measures of scientific performance in different organizations. Chapter 2 will point out several different techniques that have been employed to determine scientific performance. Additionally, there is no consistently defined term for scientific performance. Depending on the investigator, terms such as creativity, innovation, productivity and output have all been used.

Stahl (1975) confronted these many dissimilarities when he prepared an extensive literature survey in his investigation to determine a set of organizational variables that was associated with innovation and productivity of scientists and engineers (Ref 22). His survey included most of the 87 previously referenced studies along with numerous others. Chapter 2 will provide greater detail concerning Stahl's investigation. However, in general, he used a peer rating technique to determine measures of innovation and productivity. These measures were compared to measures of organizational and individual variables obtained through the use of

a questionnaire completed by the scientists and engineers in three Air Force R&D laboratories.

Rather than using a peer or supervisor rating of productivity, the issue to be explored in this effort is, what are the relationships between an objective, quantifiable measure of scientist/engineer productivity and certain selected organizational and individual variables?

The Problem and Its Limitations

Specifically, what are the relationships between certain organizational variables and output of working level scientists/engineers in an Air Force R&D laboratory? Do these relationships change when a weighting scheme is applied to the multiple dimensions of output? How do these relationships compare to those developed from a peer rated measure of productivity?

The questions posed above indicate the limitations within which this research will be accomplished. First note that this research effort is not concerned with an investigation to determine an all-inclusive set of organizational variables to be tested, or even a "best" set. It does include the selection of variables that, in previous studies, have been shown to be correlated to some definition of scientific and engineering performance. For purposes of comparison, the set of variables utilized is similar to the set investigated in Stahl's effort.

Second, the dimensions of scientific performance must fit the objective, countable criterion. That is to say, the

somewhat subjective notions of creativity and innovation are not being measured except to the extent that they are reflected in the tangible output of the scientist/engineer. Strict adherence to this criterion of scientific performance does have an inherent limitation, centered on the notion of non-equality of content of the various types of tangible scientific and engineering output.

Previous empirical studies have attempted to minimize the effects of this non-equal content aspect through the application of a weighting scheme in the form of subjective ratings of the individual scientist/engineer. Any set of subjective weights is limited by the accuracy and reliability of the method used to determine the weight.

Finally, there is a limitation on the sample size of scientists/engineers to be tested due to time and cost constraints. This effort is limited to the data gathered from a single Air Force R&D laboratory.

Research Objectives

1. Modify the questionnaire developed by Stahl to measure similar R&D organizational variables.

2. Develop a questionnaire for use in determining a weighting scheme to be applied to output dimensions.

3. Develop a questionnaire enabling respondents to report their objective output.

4. Determine the relationships between organizational variables and both weighted and unweighted output.

Chapter II. Literature Review

Introduction

A review of the pertinent literature was required to familiarize the researcher with the previous studies that have been conducted. This familiarization was required to gain an understanding of (1) the aspect of scientist/engineer productivity investigated, (2) the various individual and organizational variables investigated, (3) the measurement techniques employed and (4) the findings reported.

As noted in Chapter 1, a recent literature review was conducted by Stahl in 1975, identifying the major studies conducted during the previous fifteen years. Consequently, what follows in this chapter is, for the most part, a summary of the studies, articles and postulations that were reviewed by Stahl. Also described however, are some studies not included in Stahl's review.

Scientist/Engineer Productivity Measures

Vincent and Mirakhor state,

> "It is important to note at the outset that the study deals with an area of research in which, despite overwhelming volume of empirical studies, there is considerable confusion not the least of which concerns the terminology used. The difficulty generally stems from the fact that there is little agreement among the researchers on the definition of terms used." (Ref 24:45)

The confusion alluded to is certainly evidenced by the various measures of scientific and engineering productivity used in empirical studies. Terms such as performance, inno-

vation, creativity and productivity have all been used in different studies, referring to that which is representative of the output of a scientist/engineer.

Given the quantitative thrust of this research, the question became, what are the objective measures of scientist/engineering productivity?

As noted by Stahl (Ref 22:85), Pelz and Andrews included in the list of scientific output

> "...(a) patents or patent applications, (b) published papers, (c) books and (d) unpublished technical manuscripts, reports or formal talks."

Mullins (Ref 15:52) used the number of publications regardless of content area along with individual supervisor ratings as a measure of productivity and Meltzer and Salter (Ref 14:351) asked respondents to report the "number of research papers published in the last three years."

In Eiduson's study on change in productivity rate, the index of productivity was the number of scientific publications (Ref 7:57).

Hill used the publication rate as his measure of productivity because the "assessment of publication rate was a key indicator of scientific productivity to more senior management" (Ref 10:13).

In conjunction with a subjective rating, Farris used a self report by the scientists/engineers on number of patents/ patent applications, number of unpublished technical reports, and number of formal talks, as his measure of productivity (Ref 8:9). Andrews and Farris also used a peer rating in

conjunction with a self report on number of technical reports authored (Ref 4:497).

As is somewhat apparent from the above, many researchers recognized the problem of non-equal content when using a strictly quantitative output measure of productivity. That is to say, that many researchers were concerned that quality, value, importance or other content factors were different from one output type to another. Consequently, subjective aspects of scientist/engineer output, such as creativity and innovation were measured through the use of supervisor or peer ratings. These subjective ratings of individual productivity were then combined with reported output to obtain a composite productivity measure.

The peer rating utilized by Andrews and Farris (Ref 4:497) requested the individual's peers to rate him on productivity, innovation, contribution to science and usefulness of products. Farris (Ref 8:9-16) asked the individual to provide a rating on contribution to the scientific discipline and usefulness to the organization.

Pelz (Ref 16:310) also used a peer rating, averaging the ratings of as many as 14 peers per individual to obtain a performance measure. Andrews also used a peer rating on contribution and usefulness to determine a productivity measure (Ref 3:184).

The above cited studies are examples of commonly used methods for measuring scientist and engineer productivity. Those being either strict quantitative measures, or quanti-

tative measures used with subjective peer or supervisor ratings of contribution and usefulness. In addition to these techniques, Stahl's review of literature (Ref 22:34-66) includes studies that have one or more of the following types of productivity measures:

1. Self rating on creativity/innovation,
2. Supervisor or peer ratings of communication skill and skill with people,
3. Additional quantitative measures such as awards received, promotion rate, percent of projects on schedule and percent of projects within cost, and/or
4. Scores on specific creativity tests such as Remotes Associates Test and Guilford Tests.

It is interesting to note that none of the studies specifically cited above, or the additional measurement techniques listed, apply a weight to the output itself, but rather they apply a weight to the individual scientist/engineer. In only one instance did the researcher find a study that applied weights to specific quantitative dimensions of output. Vincent and Mirakhor (Ref 24:50) used technical papers published, patent disclosures or inventions, and presentations made as a measure of productivity. They noted that,

> "However it is not considered that these three indicators are of equal difficulty or importance. For management decision-making purposes, the following weighting was established within the organization: 5 on patents, 3 on papers and 1 on presentations."

Vincent and Mirakhor applied these weights to the output as

reported by the individual scientists and engineers to establish a weighted output measure. Not included in their findings however, was an indication of the degree of correlation between the weighted and unweighted measures. As this research is concerned with similar weighted and unweighted measures, this information would have been of value for comparison purposes.

Table I below presents a summary of the productivity measures described in this section.

<u>Table I. Productivity Measures</u>

A. Quantitative Measures	1. Patent/patent application
	2. Published reports
	3. Unpublished manuscripts
	4. Journal articles
	5. Books
	6. Formal talks
	7. Productivity rate
	8. Inventions
	9. Awards received
	10. Promotion rate
	11. Percent project is on schedule/within cost
B. Qualitative Measures	1. Supervisor/peer/self ratings on:
	a. Contribution to scientific discipline
	b. Usefulness of products
	c. Innovation
	d. Productiveness
	e. Creativity
	2. Creativity tests:
	a. Remote Associates
	b. Guilford
C. Weightings	1. Based on individual
	2. Based on output

In sum, there is a vast number of empirical studies and

postulations concerning various measures of scientist/engineer productivity, ranging from pure objective counts of output to purely subjective peer rating measures. Interestly, however is the fact that only one of the studies noted used a weighting scheme applied to output dimensions. Consequently, one of the objectives of this research is to develop and employ a weighting scheme that is applied to a list of quantitative output dimensions.

Organizational/Individual Variables

Identification. The list of individual, group and organizational variables that have been investigated in previous studies is quite extensive. Martino (1973) divided 53 variables into eight separate categories (Ref 12:69-70). These categories, with some examples of variables in each, are listed in Table II.

Table II. Martino's Variables

Variable Category	Examples
Controllable Variables (Climate)	project organization, leadership style, diversity of work
Controllable Variables (Physical)	equipment, funding, group size
Uncontrollable Laboratory Variables	time in organization, project phase, type of activity
Personal Characteristics (Inherent)	psychological test scores (Guilford, RAT)
Personal Characteristics (Acquired)	prior employment, academic major, degree level

Table II. - continued

Variable Category	Examples
Personal Characteristics (Descriptive)	age, time since degree
Intermediate Variables	job satisfaction, awareness of management desires
Researcher Activities	consultation with others in the laboratory, attendance at professional meetings

Similarly, Stahl categorized 117 variables that were "statistically significant or substantial" into four general categories. These categories, with some examples of variables in each, are included in Table III.

Table III. Stahl's Variables

Variable Category	Examples
Group Variables	group heterogeneity, frequency of communication, group age, size
Supervisor Variables	frequency of contact, participation in project selection, reward structure
Other Variables	salary, diversity of activities, laboratory budget
Statistical Control Variables	length of experience, type of work, time in laboratory division

Tables II and III provide an indication of the diversity of the kinds of variables that have been investigated

in previous studies. It was from this list of variables that a set to be investigated in this research was selected. Chapter 3 presents more on the selection of the variables that were investigated.

Correlates of Scientist/Engineer Productivity. As an objective of this research is to provide a basis for comparison to Stahl's effort, the identification of the organizational and individual variables that he showed to be significant correlates of peer rated measures of productivity and innovation is in order.

Variables that Stahl showed as being negative correlates of both innovation and productivity were age, length of time as a scientist/engineer, and length of Federal Government employment. Positive correlates of both criteria were shown to be education and frequency of communication with other scientists/engineers in the same group. Additionally, the perceptual variables of pressure concerning the relevancy of work to the Air Force mission, participation on project selection, empathy and rewards for innovation were all significant positive correlates of productivity (Ref 22:152-153). Stahl noted that these findings were supported by the results of numerous other researchers (Ref 22:155).

Vincent and Mirakhor failed to mention the degree of correlation between weighted and raw output. However, they did find age, job satisfaction, and ability (education) to be correlates of a weighted productivity measure, similar to the one used in this research (Ref 24:50).

Hill (1970) reported that a change in leadership style from permissive/democratic to autocratic, caused a significant reduction in the publication rate of not only the supervisor's immediate subordinates, but also in the publication rate of scientists in an associated section (Ref 10:10-20). Pelz found that "high contact (more than several times weekly)" between scientists and "colleagues who are on the average dissimilar" was an individual variable associated with high performance (Ref 16:314-315).

Meltzer and Salter found that laboratory variables such as funds available and facilities, and individual variables such as ability and job freedon were correlates of productivity (Ref 14:351-362). Farris reported that the variables, highest degree earned, length of time since degree and length of time with laboratory accounted for 80 percent of the variance in scientist/engineer performance (Ref 8:9-16).

In relating productivity rate to age, Eiduson found that productivity rate remained constant or increased up to the age of 60 (Ref 7:57-63). Andrews found that education, length of work experience, type of research setting and time between earning a B.S. and PhD were all correlates of productivity (Ref 3:185).

To summarize, there is a preponderance of organizational, group and individual variables from which to choose, that have been shown to be significant correlates of scientist/engineer productivity. An investigation of the majority of these variables to determine a "best set" is outside

the scope of this research. However, from this list a set will be selected for investigation of its association with a quantitative measure of productivity.

III. Methodology

Introduction

What follows is a description of the methodology employed during the conduct of this research effort. Included are sections concerning (1) the measurement techniques employed, (2) the selection and characteristics of the subject sample, and (3) the analytic methods utilized. Where appropriate, each of these sections includes justifications of the action taken and the methodology employed.

Application of the Questionnaire

As can be gathered from a review of the empirical studies noted in Chapter 2, the use of a questionnaire as a data collection technique is commonplace in this area of management research. The use of the questionnaire has the advantage of providing a large volume of data in a relatively short period of time when compared to an alternative method such as personal interviews. This aspect alone made it particularly favorable in light of the time and money constraints under which this research was conducted. Additionally, the questionnaire used by Stahl was in existence and pretested. With only a few modifications, that questionnaire was adequate to obtain part of the data required for this research.

The survey instrument used in this effort was composed of two separate questionnaires. Part I was sent to first level supervisors and was designed to provide a weighting scheme to be applied to the various dimensions of scientist and engin-

eer output. Part II was sent to working level scientists and engineers and provided a measurement for the organizational variables in question and the quantitative output of the individual scientist/engineer.

Output Measurement

Criteria. The overriding criterion used in the determination of a list of output to be investigated was that it be objective. That is only scientist/engineer output that was a countable, tangible product was included.

A preliminary list was compiled from a review of the empirical studies cited in Chapter 2 and from the researcher's own experience. This list included (1) test reports, (2) test plans, (3) journal articles, (4) patent/patent applications, (5) contract statements of work, (6) hardware/software specifications, and (7) oral presentations.

This list was later modified as explained in a following section, however an additional criterion for inclusion is perhaps obvious , even from the preliminary list. Only those types of output that are considered non-routine and non-administrative in nature were included in the list. As can be gathered from the final list, this criterion did not eliminate types of output such as management presentations, which might be more communicative in nature than more classical scientist/engineer output such as technical reports and journal articles, which involve a more investigative and experimental orientation. Nor were output dimensions such as

procurement package preparations and evaluations of proposals eliminated, both of which are quite representative of an engineer's productivity in an Air Force R&D laboratory.

Items such as weekly progress reports, daily consultations with peers, and other routine type activities were not deemed appropriate measures of productivity. Also eliminated were items such as effectiveness ratings (OER's) preparations and public relations activities which, although non-routine, cannot be considered output of a scientist/engineer.

Additionally, certain types of output, which may be considered representative, did not fit the objective, countable criterion. Items such as coordination with other government agencies, although perhaps representing a major amount of a scientist/engineer's workload, did not lend itself to quantification.

In sum then, the primary considerations for inclusion in the list were the objective, countable criterion and the non-routine, non-administrative aspect of the types of output that indeed were countable. With these considerations, in mind the final list of output dimensions was established.

Identification/Measurement. During a brief meeting in June with representatives of the Air Force laboratory to be investigated, the preliminary list of output dimensions, cited in the previous section, was discussed. These representatives expressed a desire to further review the list with the objective of modifying it to include output dimensions that more closely resembled the output types of the partic-

ular laboratory. A subsequent trip to the laboratory was recommended.

In July the researcher personally visited the facilities at the laboratory and part of the two-day trip was concerned with finalizing the list of output dimensions. It became apparent that a major consideration in finalizing the list of output dimensions was to ensure that it included items that were readily identifiable to those who were reporting their output and to those who were to apply weights. With this additional consideration in mind, the final list of output included (1) technical reports, (2) work unit planning documents, (3) journal articles, (4) procurement packages, (5) evaluations of proposals, (6) computer codes, (7) technical presentations and (8) management presentations.

From the preliminary list, test reports and test plans were combined into the technical report category. The justification for this action was primarily due to the fact that, in the particular laboratory in question, test plans and reports were generally prepared for the purpose of inclusion in a full technical report. It was felt that the use of technical report, in lieu of test reports/plans, would insure less confusion on the part of the respondent from a reporting stnadpont. The phrase, "including test reports" was added for further clarification.

The preliminary category of oral presentations was divided into technical presentations and management presentations. This again was done primarily to improve the reporting accuracy of the respondent. The phrase "includ-

ing those made outside the laboratory" was added to emphasize the point that routine consultation and reporting to supervisors or peers was not to be reported. The phrase, "budget reviews, for example" was added to provide a differentiation between the technical and management orientation of the presentation. It was expected that this would enhance the ability of the weighters and the output reporters to accurately respond.

The contract statements of work was divided into procurement packages and evaluations of proposals. This division allowed the weighters and the output reporters to differentiate between the two aspects, preparation and evaluation, of the contract statement of work item.

Neither the patent/patent application item or the hardware/software specification item were included in the final list, per recommendation of the laboratory personnel consulted. Concerning patents, they noted that none had been applied for by individuals in the laboratory for several years and consequently patents did not really represent the output of the scientists/engineers in that laboratory. It is somewhat understandable that patents would be uncommon in this particular laboratory, which deals with highly sophisticated and national security sensitive weapons systems.

Hardware/software specifications, although a major type of output in defense weapon system development, again was not considered representative. There were scientists and engineers in the laboratory that reviewed defense con-

tractor-submitted specifications, however few actually engaged in the total preparation and development of specifications.

The journal article item was retained in the final list. However the phrase, "either published or submitted," was added to further enhance reporting accuracy on the self-report portion of the questionnaire.

Items in the final list that were not in the preliminary list were, work unit planning documents and computer codes. A work unit planning document is a report concerning a project or particular portion of a project. This type of document would include information concerning scheduling, funding and manpower requirements for the project, in addition to identifying required external agency support. A computer code is essentially a computer program developed to meet either simulation or analytic requirements of a particular laboratory project. It was pointed out by the laboratory personnel interviewed that these items did in fact represent a measure of scientist/engineer productivity that met both the non-routine, non-administrative criterion and the objective, countable criterion.

A final category titled, "other" was added to allow the respondent to report types of output that may not have been specifically identified.

With the final list thus established, a questionnaire was developed asking for a self report on the numbers of each type of output prepared, presented, authored and/or co-

authored over a given period of time. The time period chosen for investigation was that of the most recent two years.

The two year period was chosen for two primary reasons. There was a desire to associate the output reported with the organizational variables present in a given functional section or group. Consequently, the applicable reportin time period must be such that it generally corresponded with the period of time the respondent was located in a given section or group. Due to the turnover rate and individual scientist/engineer mobility within the laboratory, it was felt that only a minority of prospective respondents would have a length of time in a given section of three or more years. Using a two year time period, a greater number of respondents would have time in section generally corresponding to the output reported. It was also felt that the respondent could more accurately recall his output over two years rather than over a three year period. Additionally, it was felt that a period greater than one year was required to ensure that the respondent's output was a function of the organizational variables measured in his present section and not a function of a prior set of organizational variables.

With the list and time period thus established, the respondent was simply asked to report the quantity of each type of output over the two year period. This report established the raw output measure of scientist/engineer productivity being used in this research effort. The weighting scheme, described below, was then applied to the reported raw output and a weighted output was established for each scien-

tist/engineer.

Weighting

Objective. As touched on in Chapter 2, a major drawback in using a strictly tangible output measure of productivity centers on the notion of non-equality of the content of various dimensions of output. That is to say, not all types of output can be considered equal in importance or value . Also as noted by Stahl (Ref 22:87-88) the raw numbers of publications and presentations in many cases is a function of the organizational emphasis and mission. Additionally, in the Air Force, security considerations may present further limitations to the productiveness of a scientist/engineer in terms of patents, journal articles and other items that would otherwise be subject to public dissemination.

By employing the questionnaire directed at the first level supervisor, an attempt was made to reduce the effects of this non-equality notion. That is, an attempt was made to determine a weighting scheme that would replace the equally weighted raw output which is implicitly used with a strictly quantitative output measure of productivity.

Previous studies employing a peer rating or supervisor rating of individual productivity, innovation and/or creativity, have been combining, in many cases, an objective measure with a rating of the individual's contribution to science, originality of work, usefulness of products or some other subjective aspect of scientist/engineer productivity. In effect, this type of productivity measure involves the

application of a weight, not to the type of output, but to the individual himself. There are certain drawbacks to the individual rating technique. Stahl (Ref 22:187) points out the need to have 4 to 5 raters per ratee to obtain a higher reliability rating. This may not be possible due to the limited number of peers or raters that are familiar enough with the individual in question to provide a fair rating. Additionally, Stahl notes the difficulties of using a peer rating, that are encountered by a researcher who requires a reasonable response rate from a questionnaire.

These two issues, along with a desire to place a weight on the type of output, rather than on the individual himself, were the reasons for discarding the peer rating technique. The questions then become, who should be asked to apply the weight to the set of output dimensions, and what should the weighting criteria be?

Criteria. In order to determine who should apply the weights, the criteria for weight determination must first be established.

It is important to understand that the researcher was desirous to have an output weighting scheme for the laboratory as a whole, rather than a multiple set of weights to be applied according to division or branch within the laboratory.

The whole notion of productivity used in this research effort is output oriented. This means that regardless of inputs such as time, money, and effort expended by the scientist/engineer, the productivity measure was strictly his

output, i.e., what he has to show for his effort.

With these understandings, it was incongruous to ask the weighters to base their weights on the notion of the amount of input required to produce the output. Another criterion must be used.

The criteria finally decided upon were based on the idea of value or importance to the laboratory as a whole. Each weighter was asked to apply a weight that he felt best represented the "relative importance" of that type of output to the laboratory in question. This criterion best fit the conceptual framework of the researcher in that the weights were not being based on the input required to produce the output dimension being weighted. Also, the weighters were required to view the output in its importance to the laboratory as a whole and not just a particular (their own) portion of it.

With the criteria established, the selection of the weighters could then be made.

<u>Selection of First Level Supervisor</u>. Given that weights were to be applied on the basis of relative importance to the laboratory in general, it was necessary to choose a set of weighters who (1) had a feel for the value of each type of output and (2) did not totally base their weights on the particular output produced in their own section or group. Additionally, the set of people to apply weights must comprise a sample large enough to provide a reliable measure from a statistical standpoint.

The first group to be considered and subsequently dis-

carded were the working level scientists and engineers. Although this group offered the largest sample from which to choose, the researcher felt that the applied weights would be overly biased, favoring the type of output with which the working level scientists/engineers were most familiar. It was felt that this bias would be furthered compounded due to the fact that these same persons would be completing the self report of output. It seemed natural that they would weight those dimensions reported more heavily.

Another group of possible weighters were individuals at a higher level of supervision such as division and branch chiefs which are somewhat removed from the working level. This group would not suffer from the same bias as that of the working level group and would probably have a better feel for the importance of certain types of output to the laboratory as a whole. However, it was felt that this group, being removed from the working level, may be familiar only with the major types of output, more common at the working level.

The group that was chosen as being in the best position to apply the weights were the first level supervisors. This group was large enough to provide a weighting scheme that was reasonably reliable. Additionally, that group was close enough to the working level to have a feel for a wide range of output types and yet one level away from the working level, so that it had a better feel for output importance at the laboratory level.

<u>Weighting Instrument</u>. The development of the ques-

tionnaire for collecting the weights and determining the final scheme was then accomplished.

Using the list of output dimensions that was utilized in the working level self report, the first level supervisors were asked to place a weight on each type of output that they felt best represented its relative importance to the laboratory. In order to provide a common point of reference, these weights were to sum to 100 on each questionnaire.

The mean of the weights for each type of output obtain- from this questionnaire was then used as a basis in the determination of the final weighting scheme to be applied to the raw output reported.

Predictor Variable Measurement

Criteria. Chapter 2 pointed out the wide variety of organizational, group and individual variables that have been investigated regarding research productivity. As noted in Chapter 1 however, the determination of a "best" set of variables that impact scientist/engineer productivity is beyond the scope of this research effort. Instead a list of variables was chosen from those that had been shown in previous studies to be correlated to a measure of scientist/engineer productivity.

The list of organizational/individual/group variables, compiled by Stahl (cited in Chapter 2) included 117 different variables that had been shown to be either statistically significant or substantial in their relation to research

productivity in one or more studies. The criteria used to select from that list a set of variables to be investigated were (1) an understanding that not all the variables on that list could ve investigated, (2) the desire to provide a basis of comparison to Stahl's findings and (3) the recommendations of the laboratory personnel interviewed. With these criteria in mind, a preliminary questionnaire was developed from the one used by Stahl to measure the variables included in his research. This questionnaire was then the basis for discussion with the laboratory personnel visited in July. The result of that meeting was the identification of the final list of predictor variables to be measured with the questionnaire.

Identification. The list of predictor variables that was decided upon is contained in Table IV.

Table IV. Included Variables

1. Age
2. Grade/rank
3. Education level
4. Length of time in current section/group
5. Length of time under current supervisor
6. Years of scientific/engineering experience since first degree
7. Communication with other colleagues in same section/group
8. Communication with scientists/engineers outside section/group
9. Communication with supervisor
10. Pressure for quantity of output

Table IV - continued

11. Pressure for quality of output
12. Pressure for meeting schedules/deadlines
13. Pressure for relevancy of work to the Air Force mission
14. Degree of participation in setting work goals
15. Degree to which quantity of output is rewarded
16. Degree to which quality of output is rewarded
17. Degree to which innovative output is rewarded
18. Extent to which supervisor evaluates work
19. Extent to which supervisor controls work
20. Extent to which supervisor understands subordinate's feelings
21. Predominant nature of work
22. Frequency of attendance at professional society meetings
23. Organizational membership in the laboratory, i.e., Office A or Office B (described in the following section)

Measurement. The instrument used to measure all the predictor variables was a modification of Stahl's questionnaire. This questionnaire was designed to obtain data for subjective variables, such as the 11 perceptual variables, and for objective variables such as age, grade and frequency of attendance at professional meetings. The questionnaire is contained in Appendix A.

Subjects

Sample Selection. The criteria used in the determination of an Air Force laboratory to be investigated were (1) the number of working level scientists/engineers available to participate in the survey and (2) the degree of cooperation, i.e., response rate, that could be anticipated from the chosen laboratory.

The number of Air Force R&D laboratories located at Wright-Patterson AFB initially seemed to indicate that the selection of one or more of these laboratories would be ideal from the standpoint of close proximity and relative ease of communication. However these laboratories had been highly surveyed in the past, and at the time of this research, several of these laboratories were again being surveyed and interviewed. With the frequency of surveys being brought to these local laboratories for completion, it was felt that an adequate response rate might not be obtained. A laboratory less surveyed and researched might provide a more prompt and adequate response.

It was brought to the attention of the researcher that an Air Force laboratory, geographically located in the western half of the United States, had shown some interest in the work done by Stahl. After consultation with a representative of the prospective laboratory it was tentatively agreed that this laboratory would participate in the survey, and during a meeting in June, the laboratory commander stated his full cooperation with the research effort.

During the visit to the laboratory in July, the research-

er received a list of all the personnel in the laboratory. This list included approximately 390 working level scientists and engineers and 101 first level supervisors. Organizationally, the laboratory was divided into primary offices. For use in this text, these offices will be referred to as Office A and Office B. These offices had two separate missions and in recent years Office A had been receiving a higher priority both in funds and personnel, although Office B still contained about twice as many scientists/engineers. The scientists/engineers in these offices might be categorized as physical sciences oriented as opposed to a human resources or biomedical orientation.

From the lists received, 349 working level scientists and engineers and 91 first level supervisors were randomly chosen to receive questionnaires. The number of working level scientists/engineers selected was based on an approximate anticipated response rate of 60 percent to provide a total of 200 respondents. It was estimated that 200 respondents would provide an adequate sample size for the statistical analyses contemplated.

Sample Characteristics. The overall response rate for Part I of the survey, which was the first level supervisor questionnaire, was 65 respondents out of a possible 91, or 71.4 percent. Of the 65 respondents, a total of 12 were discarded. One was discarded because the weights did not sum to 100 as directed. The other 11 had filled in the "other" category and applied a weight to that write-in dimension. There was no consistently identified dimension among these 11.

This yielded a usable response rate of 58.2 percent (53 of 91). The range of time as supervisor was from 1 month to 12 years, with the mean time being 1 year, 11 months. The median time was 1 year, 3 months, with 90.6 percent of the respondents having 3.2 years or less as supervisor of their current section or group. These characteristics are displayed in Table V.

Table V. Supervisor Sample

Response Rate	
Overall	71.4% (65/91)
Usable	58.2% (53/91)
Time as supervisor(yrs)	
Range	.1 to 12.
Mean	1.94
Median	1.31

The overall response rate for Part II of the survey, the working level scientist/engineer questionnaire, was 184 of a possible 349 or 52.9 percent. Of the 184 respondents, 49 were not included in analysis for the following reasons:

1. 26 were a member of their current section or group for less than one year.

2. 13 had failed to answer questions on one or more predictor variables on which analysis was contemplated.

3. 8 had reported output for a particular dimension that exceeded five standard deviations from the mean of that dimension, indicating a probability that they had over-

looked the stipulated two year reporting period. A check of laboratory records to determine the highest number of each output type produced over the past two years was not made. Given that limitation, to insure that the reported output was relatively accurate, these eight outliers were discarded.

4. 2 respondents did not have academic degrees and consequently were not considered scientists/engineers.

With these 49 discarded, the usable response rate was 135 for a rate of 38.7 percent. This sample size is somewhat less than the anticipated 200. The impact of this size is evident in the section concerning canonical correlation analysis.

Age, education and grade characteristics of this sample are displayed in Table VI.

Table VI. Scientists/Engineers Sample

Response Rate	
Overall	52.7% (184/349)
Usable	38.7% (135/349)
Age (years)	
Range	24 to 57
Mean	33.5
Median	31.4
Grade (% of total)	
GS-7,8,9, NCO	05.9
Lieutenant	13.3
GS-10,11,12, Capt	58.5

Table VI - continued	
Grade(continued)	
GS-13, Major	17.0
GS-14, Lt Col	05.2
Civilian/Military	45/55
Education Level (% of total)	
BS	31.1
MS	48.1
PhD	20.7

Analytic Methods

Introduction. The Statistical Package for the Social Sciences (SPSS) was the primary computer package utilized for conducting the statistical analyses in this research. SPSS routines for stepwise multiple regression analysis and compilations of frequency distributions and histograms, along with typical statistical parameters were used extensively. Also the nonparametric Spearman correlation routine was used.

The Spearman-Brown Reliability Prediction formula was used to determine the reliability of the weights received from the first level supervisors (Ref 25:286).

Canonical correlation analysis was used to explore the relationship between a set of 9 output criteria and a set of 15 individual/organizational variables (Ref 23:185).

Appendix C includes the data coding employed for use with the computer package.

Validity of Output and Reliability of Weightings. The

self report of output by the working level scientists/engineers did not readily lend itself to a validity analysis. With a limited familiarity of the types of output reported, a best guess as to the reasonableness of the number reported for a two year time period could be made. A better method was through comparison to the group as a whole. If there was an individual whose reported output was five standard deviations greater than the mean, then it was assumed that he had overlooked the two year time period and that questionnaire was discarded.

The reliability of the weights reported by the first level supervisors were, on the contrary, readily subject to the Spearman-Brown formula. The weighting scheme to be utilized was based on the average of the weights applied to the eight dimensions of output. The Spearman-Brown formula involves the determination of the reliability of the mean of k judges, rating n items. In this case, k=53 and n=8. As the degree of reliability in this formula is highly related to the number of judges and because 53 judges is relatively high, a reliability value of .7 or greater was viewed as necessary to demonstrate the reliability of the weights. There are no tests for significance of this reliability estimate, however levels of less than .6 are rarely reported in literature using this reliability estimate.

After a determination of the reliability of the weights, the final weighting scheme to be employed was established. This scheme was first established by identifying the output dimension which had received the lowest average weight from

the supervisors. The weight applied to this dimension was 1. Each other dimension then received a corresponding weight greater than or equal to 1 based on the comparison of its overall average weight to the average weight of the smallest.

Correlation Analysis. Examination of the zero order correlation coefficients for statistical significance between the 10 criteria and the 23 predictor variables was performed. This identified the 15 predictors most consistently related to the 10 criteria.

Multiple Regression Analysis. It was anticipated that several of the predictor variables would be interrelated, thus partial correlations were determined through the use of multiple regression analysis. As there were 10 separate criteria of productivity (8 dimensions and raw and weighted sum), there were 10 separate multiple regression analyses. The general form of the linear model was

$$Y_i = b_0 + b_j X_j \qquad \text{where } i=1,\ldots,10 \text{ and } j=1,\ldots,23$$

Canonical Correlation Analysis. Because the 10 criterion variables were related, there was a need to perform multivariate analysis. Testing for significance in canonical correlation analysis requires pq degrees of freedom, with p equal to the number of predictor variables, and q equal to the number of criterion variables (Ref 22:119).

With 23 predictor variables and 10 criterion variables, 135 data points do not provide sufficient degrees of freedom to include all possible variables. As pointed out later

in Chapter 4, raw output and weighted output are essentially the same measure of productivity. However the fact that the correlation coefficient between these two measures was not equal to 1, perhaps indicates that the applied weighting scheme did slightly change the rank ordering of the reported output. Consequently weighted output was chosen in lieu of raw output for inclusion in the criterion variables. By eliminating raw output from the analysis, the criterion set is reduced to 9, thus increasing the number of possible predictor variables from 13 (135/10) to 15 (135/9).

The 15 predictor variables chosen were those that showed significant zero order correlation coefficients with one or more of the output dimensions.

IV. Presentation of Results

Introduction

This chapter first presents the means, standard deviations and distributions of the eight output dimensions as reported by 135 scientists/engineers. Thereafter follows the reported weights and their reliability and a comparison of the raw and weighted output distributions.

The sections on zero order correlations present the Spearman correlation coefficients among the output dimensions and between these dimensions and the 23 predictor variables, identifying the 15 variables chosen to be included in the canonical correlation analysis.

Additionally included are the results of the multiple regression analyses.

Raw Output

Distributions. The mean and standard deviation of each output dimension, for a sample of n=135, is presented in Table VII.

Table VII. Output Means and Standard Deviations

Dimension	Mean	SD*
Technical Report (TR)**	1.80	2.08
Work Unit Planning Document (WUPD)**	1.15	1.90
Journal Article (JA)**	0.80	1.70
Procurement Package (PP)**	2.04	3.02
Evaluation of Proposal (EOP)**	2.30	3.10

Table VII - continued

Dimension	Mean	SD*
Computer Code (CC)**	2.16	4.09
Technical Presentation (TP)**	2.97	4.11
Management Presentation (MP)**	2.27	4.12

* standard deviation
** These abbreviations are used extensively throughout the remainder of the text in reference to the output dimensions

A closer look at the distribution of each output dimension shows them all long tailed to the right, following a near exponential distribution. These individual distributions are presented in figures 1 through 8.

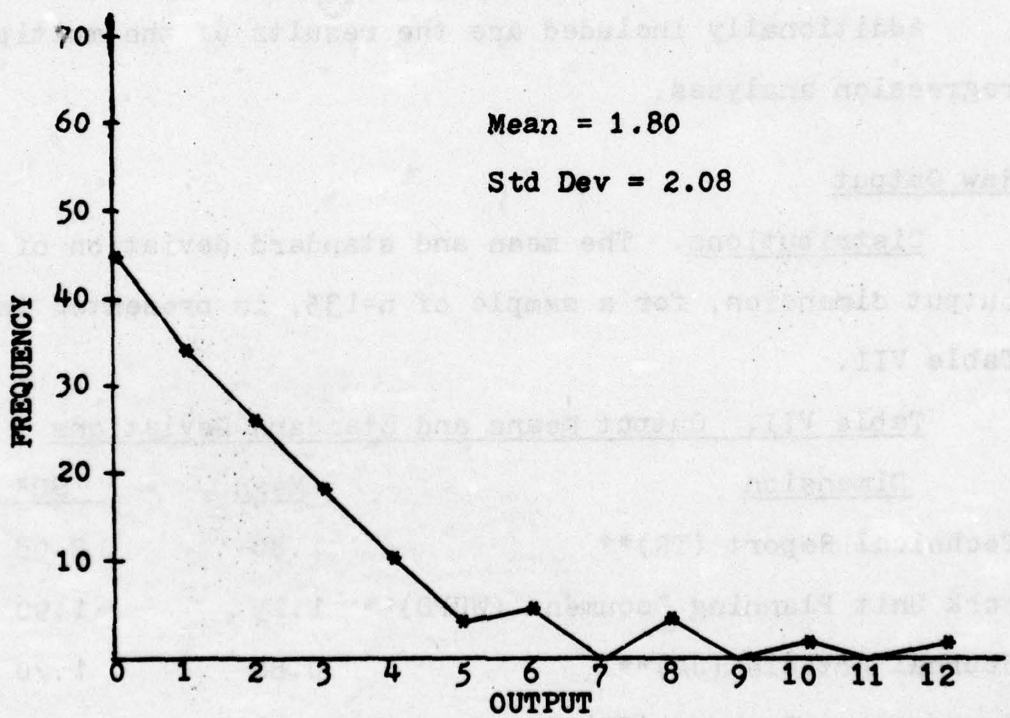

Figure 1. Technical Report Distribution

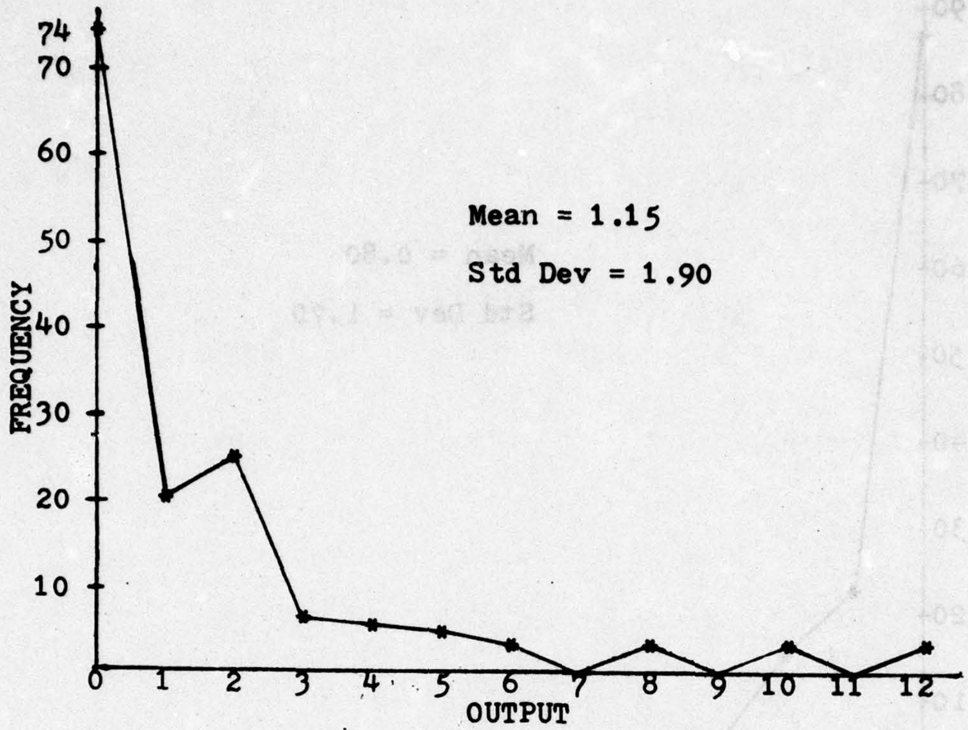

Figure 2. Work Unit Planning Document Distribution

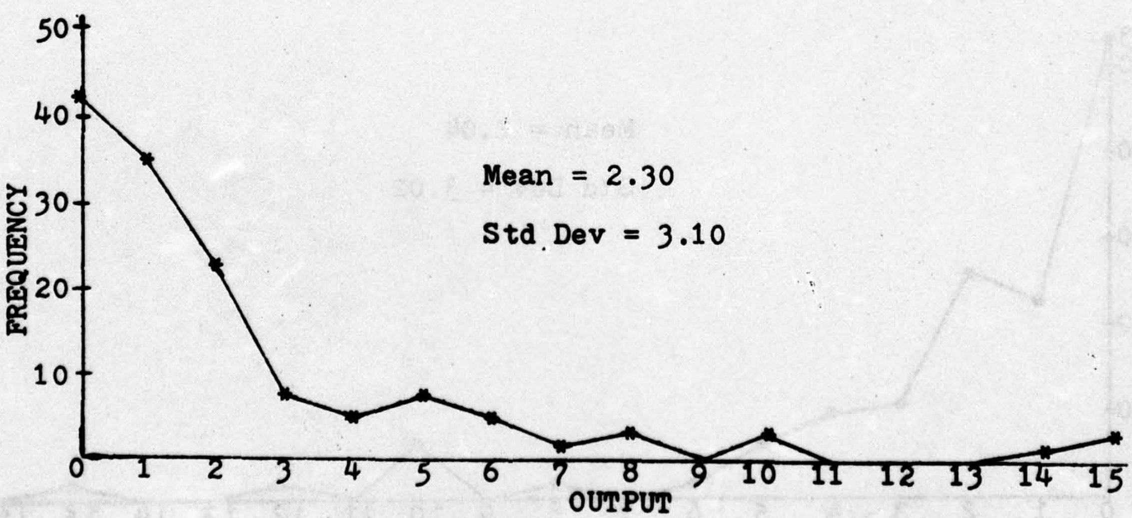

Figure 3. Evaluation of Proposal Distribution

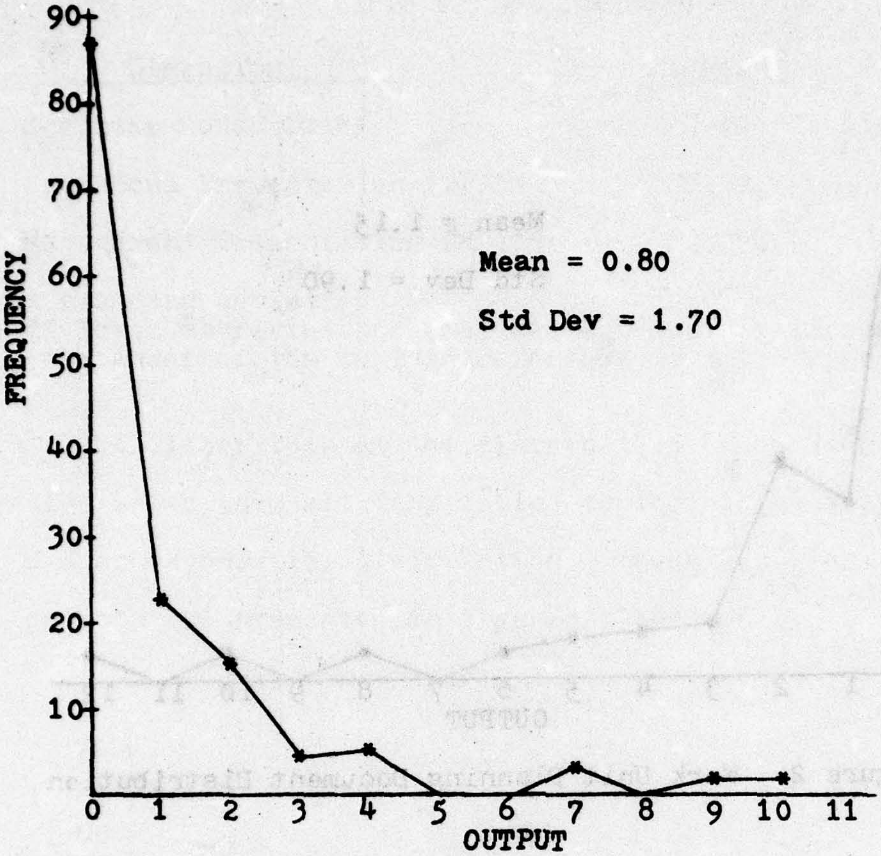

Figure 4. Journal Article Distribution

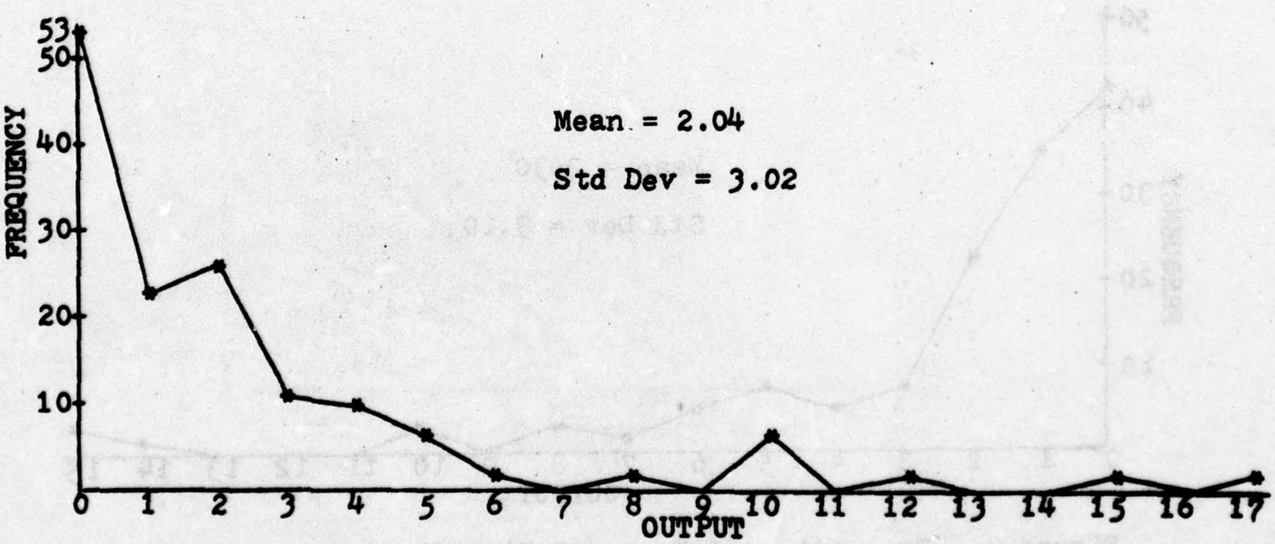

Figure 5. Procurement Package Distribution

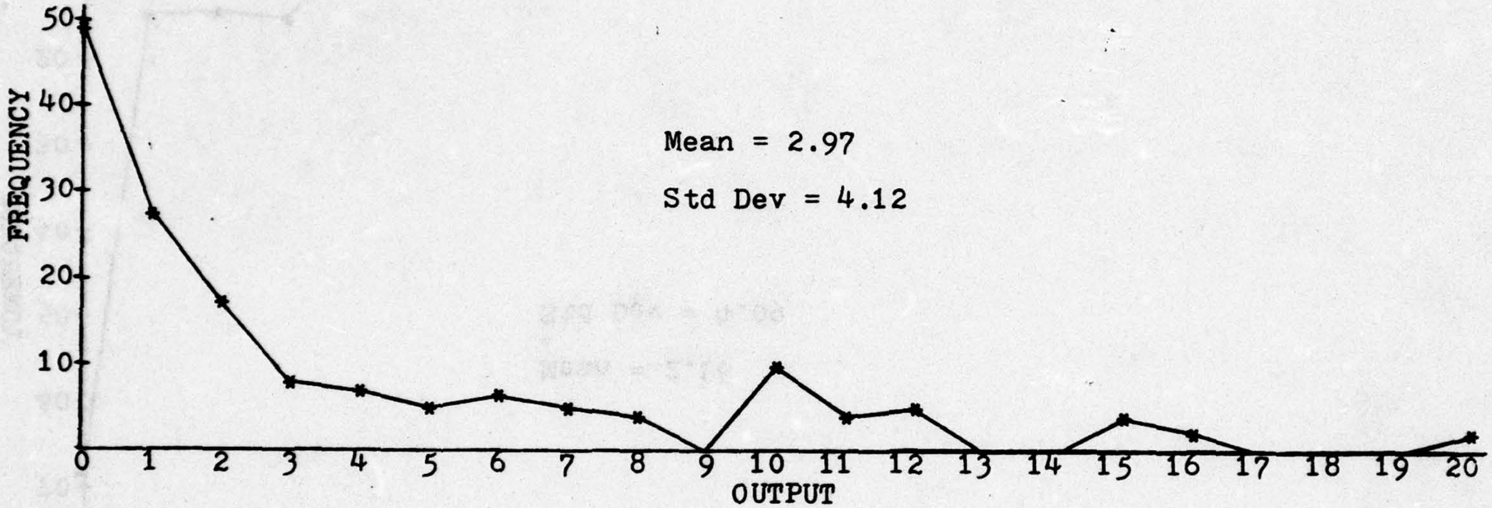

Figure 6. Technical Presentations Distribution

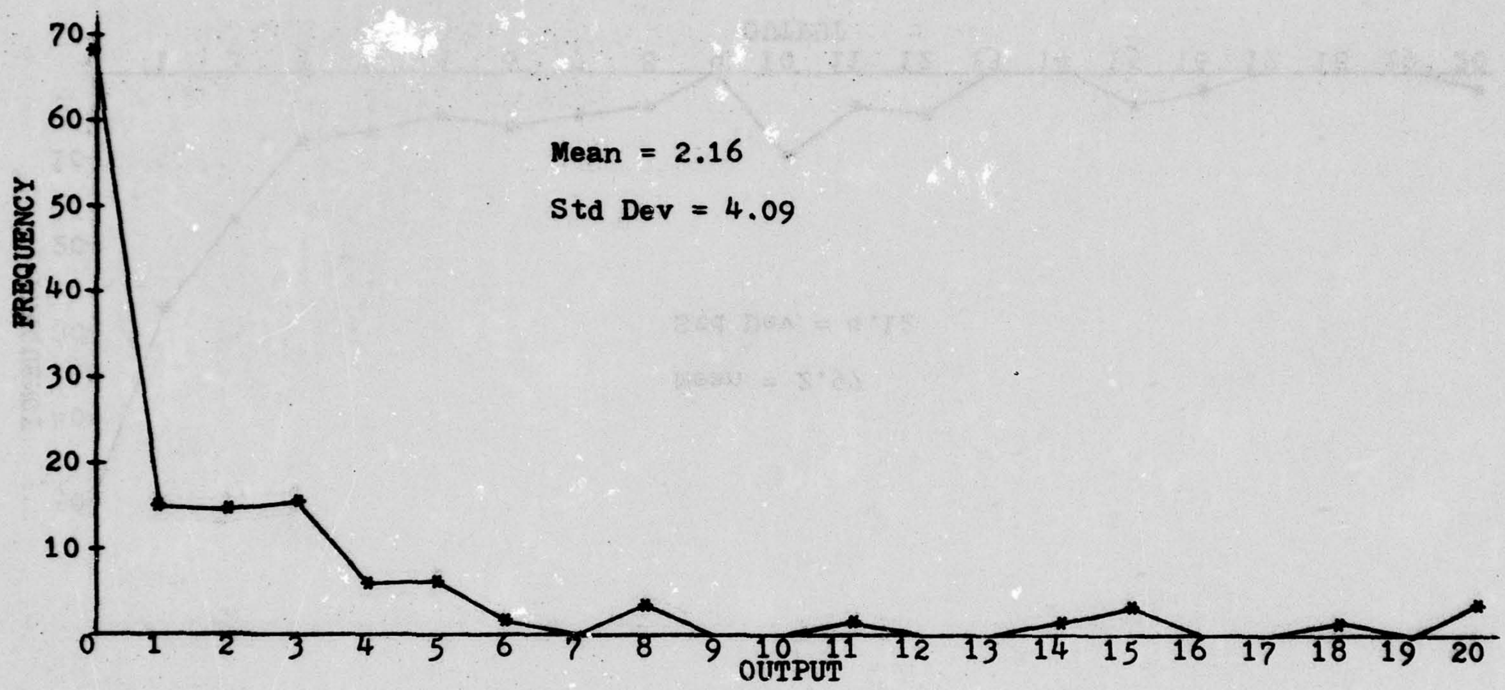

Figure 7. Computer Codes Distribution

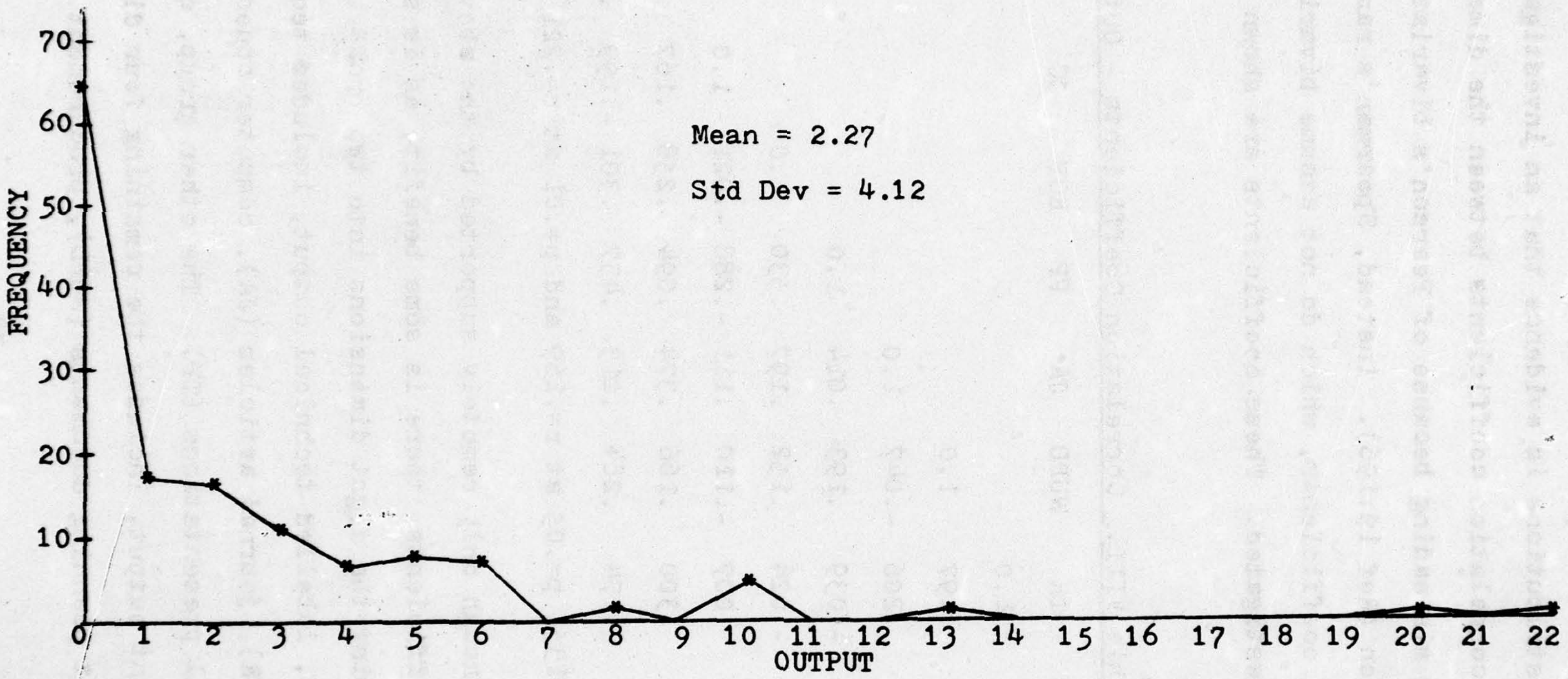

Figure 8. Management Presentations Distribution

Zero Order Correlations. The highly skewed nature of these distributions is evidence that an investigation of the Pearson correlation coefficients between the dimensions might be misleading because of Pearson's bivariate normal assumption (Ref 19:196). Instead, Spearman's rank order correlation coefficients, which do not assume bivariate normal, were investigated. These coefficients are shown in Table VIII.

Table VIII. Correlation Coefficients - Output

	TR	WUPD	JA	PP	EOP	CC	TP	MP
TR	1.0							
WUPD	.197	1.0						
JA	.206	-.047	1.0					
PP	-.039	.193	.014	1.0				
EOP	-.024	.152	.197	.530	1.0			
CC	.007	-.110	.111	-.288	-.021	1.0		
TP	.300	.186	.374	.094	.258	.167	1.0	
MP	.174	.284	.013	.437	.301	-.199	.175	1.0

For n=135, p=.05 at r=.169 and p=.01 at r=.221

Although only remotely supported by the above correlation coefficients, there is some benefit, as is shown later, in grouping the eight dimensions into two broad based types. One type, labelled technical output, includes technical reports (TR), journal articles (JA), computer codes (CC) and technical presentations (TP). The other group, contractual/ management output, includes the remaining four dimensions, work unit planning documents (WUPD), procurement packages

(PP), evaluations of proposals (EOP) and management presentations (MP).

Table VIII does point out the extent of the relationships among the eight dimensions, thus the need for multivariate analysis. Prior to the discussion of canonical correlation analysis, the weighting scheme and a comparison of raw and weighted output is presented.

Weighting

Reliability. As previously noted, the reliability of the weights applied to the output dimensions by the first level supervisors was determined by use of the Spearman-Brown Reliability Prediction formula. The mean weights applied to each output dimension are listed in Table IX. Using these weights, the Spearman-Brown formula resulted in a reliability of r'=.88, for n=8 and k=53.

Table IX. Dimensions and Mean Weights

Dimension	Mean Weight
TR	20.97
WUPD	9.18
JA	8.76
PP	13.01
EOP	9.92
CC	15.62
TP	12.77
MP	9.75

This high a level of reliability was anticipated due to

the high number of judges used. A figure of less than .70 for example, would lead one to suspect the overall reliability of the weights, but with p=.88, a high interrater agreement is demonstrated.

Determination. With the reliability of the above weights determined, the final set of weights were then calculated. For ease of calculation, the weights in Table IX were each divided by 8.76, the journal article weight. This resulted in the final weighting scheme applied to the dimensions of output, listed in Table X below.

Table X. Dimension and Weight Applied

Dimension	Weight Applied
TR	2.4
WUPD	1.0
JA	1.0
PP	1.5
EOP	1.1
CC	1.8
TP	1.5
MP	1.1

These weights were applied to the output dimensions reported by the individual scientists/engineers, providing a weighted sum measure of productivity.

Comparison of Raw and Weighted Output

Distributions. With the application of the weight to each output dimension, a weighted sum measure of productivi-

ty was determined for each scientist/engineer. For ease of presentation, both the raw output and weighted output measures were grouped into increments of ten. These groups were distributed as displayed in Figure 9.

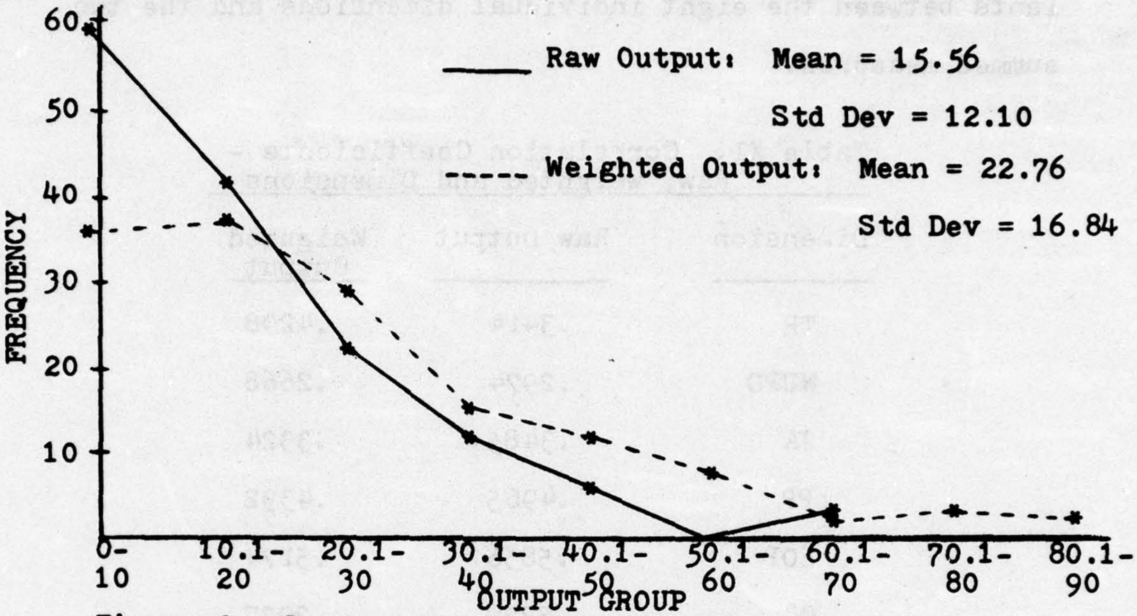

Figure 9. Raw and Weighted Output Distributions

Zero Order Correlations. The zero order correlation coefficient between raw and weighted output was somewhat surprising. Prior to its determination, it was anticipated that the weighted sum would provide a significantly different measure of productivity than the raw measure. The underlying assumption was that the raw sum would not adequately measure the scientist/engineer's productivity due to the non-equality of content notion and that a different measure, weighted sum, would take into account this non-equality notion.

Consequently it was surprising when the zero order Spear-

man correlation coefficient between weighted and raw output was r=.985. This high a correlation indicates that the two are essentially the same measure.

Table XI below shows the Spearman correlation coefficients between the eight individual dimensions and the two summed measures.

Table XI. Correlation Coefficients - Raw, weighted and Dimensions

Dimension	Raw Output	Weighted Output
TR	.3414	.4298
WUPD	.2974	.2668
JA	.3485	.3324
PP	.4965	.4392
EOP	.5856	.5174
CC	.2270	.2927
TP	.6125	.6144
MP	.5428	.4793

For n=135, p=.05 at r=.169 and p=.01 at r=.221

Predictor Variables

The means, standard deviations and zero order correlations for all 23 predictor variables are presented in Appendix B. In the discussion that follows, the sample size of 135 is retained for 21 of the 23 predictor variables. However, due to missing data, the sample size for the organizational membership variable (ORGN) is 124, and the sample size for the predominant nature of work variable (NATW) is 117.

The Spearman zero order correlations between the predictor variables and the output criteria were investigated to determine those variables which are significant correlates of one or more of the output dimensions. Additionally, from the list of predictor variables, the 15 most consistent correlates would be included in the canonical correlation analysis. The predictor list was limited to 15 variables as described in Chapter 3.

Table XII below presents the variable abbreviations and meanings that are used in the remainder of this text.

Table XII. Variable Abbreviations

Individual Variables	
AGE	Actual age of scientist/engineer
GRADE	Grade/rank of scientist/engineer
EDL	Educational level
Time Variables	
TIMIS	Length of time in current section or group
TIMUS	Length of time under current supervisor
YRSE	Years of scientific/engineering experience
Frequency of Communication Variables	
COMIS	With other scientists/engineers in same section
COMOS	With other scientists/engineers outside section
COMWS	With supervisor

Table XII - continued

<u>Perception Variables Concerning Supervisor</u>

QUANP	Pressure for quantity of output
QUALP	Pressure for quality of output
TIMEP	Pressure for meeting schedules/ deadlines
MISSP	Pressure for relevancy of work to the Air Force mission
PART	Degree of participation in setting work goals
QUANR	Degree to which quantity of output is rewarded
QUALR	Degree to which quality of output is rewarded
INNOR	Degree to which innovative output is rewarded
EVAL	Extent to which supervisor evaluates work
CONTR	Extent to which supervisor controls work
EMP	Extent to which supervisor understands feelings

<u>Other Variables</u>

NATW	Predominant nature of work
FREQA	Frequency of attendance at professional society meetings
ORGN	Organizational membership in laboratory, i.e., Office A or Office B

<u>Correlates of Raw and Weighted Output</u>. (Refer to Table XIII) The most consistent positive correlates of both the raw and weighted sum measures are education level (EDL), frequency of communication, both within and outside the sec-

tion (COMIS and COMOS), frequency of attendance at professional meetings (FREQA), participation in work goal setting (PART), and the perceived degree to which quantity of output is rewarded (QUANR). Surprisingly, age (AGE) is not significantly correlated to either of the summed measures.

One variable, organizational membership (ORGN) was negatively correlated to both measures. This indicates one laboratory office more associated with productivity than the other. Grade/rank (GRADE), perceived rewards for quality of output (QUALR) and supervisor empathy (EMP) were positive correlates of the raw sum, but although substantial, all three correlations with the weighted sum were not statistically significant at p=.05.

Only one of the time variables, length of time under supervisor (TIMUS), was significantly correlated to either of these measures, showing a negative correlation with weighted output.

Correlates of Individual Output Dimensions. There was no a priori assumption as to the existence of two or more separate types of output groups present within the eight individual dimensions. An investigation of the zero order correlates between the dimensions and the 23 predictor variables however was facilitated by such an assumption. That is, by dividing the eight dimensions into the two broad based types previously mentioned, a degree of consistency was shown concerning predictor variables that are correlates of one type of output group and not the other.

Correlates of the Technical Output Group. (Refer to

Table XIII) The technical output group includes the dimensions, technical report (TR), journal article (JA), computer code (CC) and technical presentation (TP). Education level, although showing no statistically significant correlation to any of the output dimensions in the contractual/management group, is a significant positive correlate to each of the output dimensions in the technical group. Similarly frequency of attendance at professional meetings (FREQA), communication within the section (COMIS), participation on setting work goals (PART) and time under supervisor (TIMUS) have no significant correlation with any of the dimensions in the contractual/management group, but are significantly correlated to dimensions in the technical group. FREQA and COMIS are positive correlates of journal article, computer code and technical presentation dimensions. TIMUS is a negative correlate of technical reports and technical presentations, while PART is a positive correlate of journal articles.

<u>Correlates of the Contractual/Management Group</u>. Six variables were positive correlates of one or more of the dimensions in the contractual/management group.

Years of scientific/engineering experience (YRSE), de- of supervisor evaluation (EVAL), perceived rewards for quality of output (QUALR) and perceived rewards for innovative output (INNOR) were all significant positive correlates of the work unit planning document dimension (WUPD). Length of time in section (TIMIS) was positive correlate of management presentations (MP), and communication outside the section

(COMOS), was a positve correlate of both work unit planning documents (WUPD) and management presentations (MP). Variables that had significant correlation coefficients with procurement packages and evaluations of proposals also showed significant correlations with one or more of the dimensions in the technical group. These are identified next.

Other Correlations. Six variables exhibit somewhat different characteristics than the ones thusfar noted. These variables were shown to be correlates of dimensions from both groups of output. Two variables, organizational membership (ORGN) and predominant nature of work (NATW), understandably correlate with both types of output. Just as it was negatively correlated with both weighted and raw output, ORGN was negatively correlated with six individual output dimensions, statistically significant with journal articles (JA), procurement packages (PP) and evaluations of proposals (EOP). This shows that one office in the laboratory is more associated with these types of output than the other. Predominant nature of work (NATW) was positively correlated with procurement packages (PP) and negatively correlated with technical reports (TR), computer codes (CC) and technical presentations (TP). The coding for NATW ranged from a 1 for "research" to a 5 for "contract monitoring," consequently these correlations are not surprising.

The other four variables that cut across both types of output groups were age (AGE), grade/rank(GRADE), perceived rewards for quantity of output (QUANR) and supervisor empathy (EMP). GRADE, QUANR and EMP were consistent positive cor-

relates of one or more of the dimensions. AGE however was a positive correlate of work unit planning documents but a negative correlate of computer codes.

Uncorrelated Variables. Six variables were not correlates of either raw and weighted output or any of the individual dimensions. None of the perceived pressure variables, for quantity, for quality, for meeting schedules or for relevancy of work to the Air Force mission (QUANP, QUALP, TIMEP or MISSP) were correlates. Significantly, Stahl found no correlation between the innovation, time and quantity pressure variables and his peer rated measures of innovation and productivity (Ref 22:152).

The degree of supervisor work control (CONTR), which is essentially a reflection of the scientist/engineer's perceived work autonomy, is not correlated with any of the productivity measures. This result is again supported by Stahl's research (Ref 22:153).

Frequency of communication with the supervisor (COMWS) is also uncorrelated with any of the productivity measures. This is comparable to Stahl's results.

This absence of significant correlations may lead one to question the value of these six variables as predictors of scientist/engineer productivity. Further comment on this possibility is reserved for Chapter 5. Table XIII shows the correlation coefficients between the 23 predictors and the 10 output criteria.

Table XIII. Predictor/Criteria Correlation Matrix

Variable	TR	JA	CC	TP	RO(1)
EDL	.272**	.487**	.213*	.329**	.259**
FREQA	.165	.388**	.217*	.414**	.363**
COMIS	.008	.198*	.064	.178*	.205*
TIMUS	-.200*	-.058	-.144	-.188*	-.160
PART	.009	.169*	.168	.095	.248**
TIMIS	-.062	-.073	-.146	-.006	-.121
YRSE	.072	.101	-.157	.096	.079
EVAL	-.067	.032	.030	.008	.114
QUALR	-.031	.093	.038	.130	.191*
INNOR	-.016	.137	.057	.118	.158
COMOS	.035	-.056	-.057	.107	.199*
AGE	.013	-.066	-.198*	-.002	-.005
GRADE	.162	.108	-.165	.226**	.183*
ORGN	.035	-.275**	-.050	-.023	-.206*
QUANR	.043	.187*	.028	.137	.268**
NATW	-.254**	-.150	-.265**	-.241**	.060
EMP	.010	.113	.187*	.116	.182*
CONTR	-.121	-.129	-.001	.031	.041
COMWS	-.122	.104	.101	.031	.110
QUANP	.005	.092	.062	-.064	.074
QUALP	.024	-.016	.130	-.101	-.015
TIMEP	-.071	-.115	-.025	-.121	.024
MISSP	-.058	.008	.062	-.063	-.002

(1) Raw output
* $p < .05$
** $p < .01$

Table XIII - continued

Variable	WUPD	PP	EOP	MP	WO(2)
EDL	-.035	-.017	.156	.011	.259**
FREQA	.134	-.007	.151	.140	.370**
COMIS	.126	.107	.097	.086	.186*
TIMUS	.048	.017	.051	-.053	-.186*
PART	.154	.072	.082	.119	.222**
TIMIS	.132	.020	.046	.171*	-.131
YRSE	.262**	.020	.072	.031	.061
EVAL	.209*	.153	.060	.145	.078
QUALR	.211*	.101	.098	.103	.157
INNOR	.194*	.100	.037	.041	.137
COMOS	.305**	.127	.143	.230**	.172*
AGE	.229**	-.001	.073	.055	-.027
GRADE	.246**	-.009	.142	.147	.168
ORGN	.131	-.285**	-.257**	-.038	-.181*
QUANR	.160	.186*	.200*	.162	.236**
NATW	.013	.305*	.149	.082	-.086
EMP	.101	.270**	.177*	.201*	.141
CONTR	-.005	.045	.043	.023	.027
COMWS	.022	.076	.110	.131	.096
QUANP	.050	.135	.141	.122	.051
QUALP	.003	.043	.005	.032	-.031
TIMEP	.044	.095	.097	.122	.002
MISSP	.052	.008	.056	.134	-.031

(2) Weighted output
* $p < .05$
** $p < .01$

Canonical Correlation Analysis

It was initially contemplated that the 15 predictor variables most consistently correlated to the set of output dimensions would be included in the canonical correlation analysis. However two variables, organizational membership (ORGN) and predominant nature of work (NATW), that would otherwise have been included, represented a considerable source of missing data on the questionnaires. In the sample of 135, 11 missing values occurred for ORGN and 18 occurred for NATW. Rather than removing these data points from the sample and thus further reduce the total number of predictor variables that could be included in the analysis, it was decided instead to exclude ORGN and NATW from the predictor list. A closer look at Table XIII shows a total of 17 predictor variables that are significant correlates of one or more output dimensions, of which two variables are ORGN and NATW. Consequently, the remaining 15 variables made up the list of predictors included in the canonical correlation analysis. Table XIV shows the output dimensions and predictor variables included.

Table XIV. Canonical Correlation Variables

Criterion Variables			Predictor Variables				
TR	PP	TP	EDL	TIMUS	YRSE	INNOR	GRADE
WUPD	EOP	MP	FREQA	PART	EVAL	COMOS	QUANR
JA	CC	WO	COMIS	TIMIS	QUALR	AGE	EMP

As there were nine criterion variables, there were a total of nine canonical roots formed. These results are

shown in Table XV.

Table XV. Canonical Roots

ROOTS	CHI SQUARE	d.f*	p
.4310	69.07	23	.000
.2934	42.89	21	.004
.2712	38.75	19	.006
.1951	26.58	17	.067
.1633	21.84	15	.115
.1247	16.31	13	.234
.0968	12.47	11	.331
.0661	8.37	9	.502
.0265	3.30	7	.857

* degrees of freedom

Only the first three roots are significant at p=.05, consequently the remaining six roots are no longer discussed.

As noted by Stahl, an issue with the use of canonical loadings is the determination of what magnitude is required for a loading to be substantial, since there are no significance tests for each loading (Reg 22:120). For this research it was decided that loadings of .2 or greater were substantial. That level of loading approximates the significance level of the zero order correlations. Additionally, that level allows for the verification of some variables that were significant in the zero order correla-

tion analysis. In Table XVI below, loadings of .2 or greater are underlined.

Table XVI. Canonical Loadings

Variables	First Canonical Dimension	Second Canonical Dimension	Third Canonical Dimension
TR	.5613	.0979	-.0161
WUPD	.0137	.3974	.0092
JA	.7592	-.0933	.5081
PP	-.1541	.0242	.3034
EOP	.1060	.5458	.1652
CC	.4448	-.1094	-.3469
TP	.5110	.5346	-.2409
MP	-.0452	.3367	-.0607
WO	.5843	.4243	-.0801
AGE	-.1712	.1674	-.1029
GRADE	.1558	.7613	-.1840
EDL	.7775	-.0242	.3028
TIMIS	.1705	.0990	-.2308
TIMUS	-.2410	.1399	-.2642
YRSE	-.0202	.2693	.0298
COMIS	.2446	.0604	-.0666
COMOS	-.1413	.3646	-.3097
FREQA	.5839	.2141	-.1493
PART	.2302	-.0620	-.1870
QUANR	.2389	.0153	.1080

Table XVI - continued

Variable	First Canonical Dimension	Second Canonical Dimension	Third Canonical Dimension
QUALR	.1469	-.0047	-.1369
INNOR	.1774	-.1398	-.1169
EVAL	-.0412	-.1213	.0271
EMP	-.1216	.1836	.4215

First Canonical Dimension. For the first root, in addition to weighted output, the dimensions on the criterion side interestingly correspond to the four dimensions that were included in what was labelled previously as the technical output group. This group of output dimensions, when taken jointly, might be labelled technical output as the loadings are relatively heavy on all four.

On the predictor side of the first root, the determination of a single label that would describe the various kinds of variables is difficult. However a comparison of the loadings with the zero order correlation coefficients previously described shows some consistent results.

Education level (EDL) and frequency of attendance at professional meetings (FREQA) show strong positive loadings with the joint technical output group. Similarly, EDL was correlated with each of these dimensions when taken separately and FREQA was correlated with three of the four individual dimensions. Both these variables seem to be significant, consistent predictors of the dimensions in the technical ourput group.

The loadings of communication frequency with colleagues in the same section (COMIS) and length of time under supervisor (TIMUS) with the joint criteria also support the zero order correlations. COMIS shows a positive relationship with the joint criteria just as it was positively correlated with journal articles (JA) and technical presentations (TP) individually. TIMUS, which was found to be negatively correlated to both technical reports (TR) and technical presentations (TP), shows a negative relationship to the joint criteria. Similarly, participation in work goals and project selection (PART) shows a positive relationship to the joint criteria, as it did with journal articles (JA) separately.

<u>Second and Third Canonical Dimensions</u>. An investigation of the second and third canonical dimensions provided a less clear indication of the relationships.

On the criterion side of the sceond canonical dimension were weighted output (WO), technical presentations (TP), and three of the output types included in the contractual/management group. The three contractual/management types of output were work unit planning documents (WUPD), evaluations of proposals (EOP) and management presentations (MP).

The inclusion of technical presentations in this joint criteria does not necessarily invalidate the division of the output types into separate technical and contractual/management groups. Technical presentations indeed may involve both types of orientations. Generally, the loadings in the second canonical dimension do provide support for the contractual/management and technical categories.

On the predictor side of the second canonical dimension, four variables have substantial loadings, with grade (GRADE) being dominant. GRADE was positively correlated with both technical presentations and work unit planning documents at the zero order level, but was not significantly correlated to any of the other dimensions separately. Communication with other scientists/engineers outside the section (COMOS), showing a positive relationship to this joint criteria,was found also to be correlated to WUPD and management presentations (MP) separately. Years of scientific/engineering experience (YRSE) which shows a positive relationship to the joint criteria, was shown to be a positive correlate of WUPD separately. Frequency of attendance at professional meetings (FREQA) was not correlated with WUPD, EOP or MP at the zero order level. However it was the highest correlate of all predictor variables for both weighted output and technical presentations. This may account for its substantial loading in this second canonical dimension.

An investigation of the third canonical dimension shows, on the criterion side, two output types with positive loadings, journal articles (JA) and procurement packages (PP). Also on the criterion side are two output types with negative loadings, computer codes (CC) and technical presentations (TP).

On the predictor of this canonical dimension are education level (EDL) and empathy (EMP) showing a positive relationship. Showing negative relationships are length of time

in section (TIMIS), length of time under current supervisor (TIMUS) and frequency of communication outside section (COMOS).

It is unclear as to how the criterion side of this dimension, containing both negative and positive loadings, represents scientist/engineer productivity. Consequently the relationships between the predictor variables in this dimension and scientist/engineer productivity are unclear and the third canonical dimension is not further discussed.

Multiple Regression Analysis

It was anticipated that multiple regression analysis using each of the output dimensions as a separate dependent variable, i.e., ten separate regression equations, would provide further insight as to the predictor variables that correlate with scientist/engineer productivity. It would additionally provide further basis for comparison to Stahl's research. However the analysis of residuals of the regressions revealed that an assumption for significance testing may well have been violated due to an abnormality in the plot of the residuals (Ref 6).

Appendix D shows a plot of the residuals for the regression on weighted output. That plot is typical of the plots obtained for the other nine regression models.

Because of this abnormality in the residuals, it was decided that an analysis of the partial correlations obtained from the multiple regressions would be misleading. Therefore they are not presented.

Consistent Correlates

Tables XIII and XVI show respectively the zero order correlations and the canonical loadings between the predictor variables and the output criteria. For the remainder of the text, a consistent correlate is defined as one which is both a significant zero order correlate and has a substantial canonical loading on (with) one or more of the output criteria.

Table XVII shows the predictors with significant zero order correlations and substantial canonical loadings on the first canonical dimension. Table XVIII shows the predictors with significant zero order correlations and substantial loadings on the second canonical dimension.

Table XVII. Consistent Correlates - First Canonical Dimension

Variable	Zero Order Correlation Coefficient-r*					Loading
	TR	JA	CC	TP	WO	
EDL	.272	.487	.213	.329	.259	.778
FREQA		.388	.217	.414	.370	.584
COMIS		.198		.178	.186	.245
TIMUS	-.200			-.188	-.186	-.241
PART		.169			.222	.230
QUANR		.187			.236	.239

* p=.05 at r=.169 and p=.01 at r=.221

Table XVIII. Consistent Correlates - Second Canonical Dimension

Variable	Zero Order Correlation Coefficient-r* WUPD	EOP	TP	MP	WO	Loading
GRADE	.246		.226			.761
YRSE	.262					.269
COMOS	.305			.230	.172	.365
FREQA					.370	.214

*p=.05 at r=.169 and p=.01 at r=.221

The predictor variables contained in Tables XVII and XVIII are, in a relative sense, stronger predictors of scientist/engineer performance than the other organizational and individual variables investigated. This is evidenced by the consistency of their significant correlations with both the summed and individual measures of productivity, separately and in the joint canonical dimensions.

The implication of this and the other findings presented in this chapter are further discussed in Chapter 5.

Chapter V. Discussion and Conclusions

This chapter provides comments and suggests implications of the results that were presented in Chapter 4.

Weighting Scheme

As noted in Chapter 3, there was a question in the mind of the researcher as to which sample of laboratory personnel could provide a reliable set of weights to be applied to the eight different output dimensions. As shown, the use of the first level supervisors for this purpose did provide a set of weights that demonstrated high interrater agreement. However the implication should not be made that the weights received from this sample is the only weighting scheme that might have been determined. Nor should it be implied that the weighting scheme is the one that most accurately reflects the "true value" of each output type to the laboratory as a whole. It might be postulated that the working level scientists/engineers themselves, or the higher levels of supervision could similarly demonstrate high interrater agreement. Would one then choose the weighting scheme that shows the highest reliability? Certainly there would still be doubt as to the validity of the weights. The subjective nature of any weighting scheme contains this degree of doubt, regardless of how rigorously it is defended. It is important to note that the researcher has carefully avoided stating that the best set of weights has been employed, but only that a statistically reliable set has been used.

Implications of Correlations

Raw and Weighted Output. It was interesting to find these two measures to be so highly correlated (r=.985). As can be gathered from Chapter 2, numerous researchers were so concerned with the non-equality of content notion, that the use of a peer or supervisor rating in conjunction with a tangible output count was quite common in determining an overall productivity measure.

The weighting scheme provided by the first level supervisors indicate that this non-equality of content notion (from the standpoint of importance to the laboratory) is recognized, at least by the first level supervisors. What the high correlation between raw and weighted output seems to imply is that those individuals producing low (relatively) importance output, do so in such quantities that their overall productivity ranking changes very little when the weighting scheme is applied. Conversely, those individuals producing high importance output, also produce other output in such quantities so that their ranking in raw output is relatively the same.

Predictor Variables and Output Dimensions. It is important to note initially that no single variable was shown to be associated significantly with all eight of the individual output dimensions. The variables identified in Chapter 4 as being consistent correlates of one or more of the output dimensions can be considered those that are most highly associated with the quantitative measures of productivity investi-

gated in the research. Educational level was shown to be a consistent correlate of weighted output and four of the individual dimensions both separately and with the joint criteria of the first canonical dimension. The four individual dimensions and the first canonical, with which educational level was associated, were technical types of output. This seems to imply that individuals with higher academic degrees may prove to be most productive in laboratory assignments requiring technical types of output.

The frequency of communication variables, with colleagues in the section (COMIS) and with scientists/engineers outside the section (COMOS) were both shown to be positive correlates of weighted output. It is interesting to note however that these two variables were shown to be correlates of different individual output dimensions. COMIS was positively associated with journal articles and technical presentations while COMOS was associated with work unit planning documents and management presentations. Perhaps the communication within a section reflects a sharing of homogenous expertise that might be required for a journal article or technical presentation, while the external communication reflects a degree of inter-section coordination and information gathering required for planning of projects and management presentations.

The association of the frequency of attendance at professional meetings variable (FREQA) with performance might indicate to the laboratory manager the importance of keeping his scientists/engineers current, especially in the technical

disciplines.

Two additional variables which were consistent correlates of weighted output and which should be of interest to an R&D laboratory manager are participation on work goals and length of time under supervisor, PART and TIMUS respectively. The positive association of PART with performance reflects the greater productivity of a scientist/engineer who has an active voice in his project selection and work goals. The negative association of TIMUS with performance may indicate that productiveness is enhanced by a relatively frequent change in supervisor.

Rewards for quantity of output (QUANR) was found to be a consistent correlate of weighted output. Similar to Stahl, one might speculate as to the nature of the rewards available to scientists/engineers in a Civil Service or Air Force employment. If in fact, a perceived reward for quantity of output is the opportunity to attend professional society meetings, then the laboratory manager might well be aware of the associations reported in this research.

Two other variables that were found to be consistent correlates of one or more individual output dimensions were grade/rank (GRADE) and years of scientific/engineering experience (YRSE). GRADE was, in addition to being a consistent positive correlate of work unit planning documents and technical presentations, a significant positive correlate of raw output. Similarly, Stahl found grade/rank to be a positive correlate of productivity and innovation, although not

as consistent a one as some others previously mentioned. YRSE, although a consistent correlate of work unit planning documents, did not show any significant correlations with raw or weighted output, and in a relative sense is less a predictor of performance than those mentioned.

Perhaps equally important is an understanding of the variables that show little or no association with performance. Interestingly, the degree to which the supervisor controls the work (CONTR) was a correlate of none of the productivity criteria. This variable, which is essentially the scientist/engineer's perception of his work autonomy, was similarly reported by Stahl.

None of the pressure variables, for quantity/quality of output, for meeting schedules, or for relevancy of work to the Air Force mission, showed any significant correlations. The implication of the value of pressure as a method to increase performance should be obvious.

Age (AGE) was another variable for which no significant consistent correlations were found. At the zero order level, AGE was correlated negatively with computer codes and positively with work unit planning documents. However its value as a predictor of overall performance was not substantiated by this reaearch.

Shortcomings of This Research

Although not totally supported by the canonical correlation analysis, some of the associations of predictor variables and output dimensions seem to indicate a pattern. The

application of additional statistical techniques to this data might indeed provide greater clarity concerning the existence of categories of output within the eight output dimensions investigated. The problems encountered with the residuals of the multiple regression analysis prevented that technique from shedding any additional light on the nature of the relationships.

The criterion used for determining a weighting scheme was based on the raters' perception of the importance of the output to the laboratory. There was no investigation to determine that a better criterion could have been used.

Recommendations for Future Research

As an outgrowth of this research, there appears to be at least two topics in the area of measuring Air Force R&D scientist/engineer productivity that is worthy of further research.

If the trend for a tighter military budget continues, and an equal or greater amount of effort will be required from relatively fewer resources, Air Force scientists and engineers will be required to be both managers and scientists. The types of output that a scientist/engineer will perhaps be required to produce will be budgeting, planning and more management related output, as well as the more traditional technical and research types. As this develops, the need for understanding the types of individual and organizational variables that associate with different types of output will increase. Consequently, the identification of these dimen-

sions of output and their associated variables will be important in trying to enhance productivity.

The trend of broad types of output is partially substantiated by this research. This research needs to be replicated in other Air Force R&D laboratories with additional statistical techniques utilized to further identify the broad output categories and their associated variables.

A second area is an outgrowth of the weighting determination accomplished in this research, and involves a determination of a multiple set of weights for a given laboratory. These weights, gathered from samples, organizationally located at different levels, might provide an indication of how well the various levels concur in their view of what type of output is important to the laboratory. The different weights would be a form of organizational feedback, testing how well output emphasis at the top of an organization compares to that down through to the working level.

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APPENDIX A

PART I: SUPERVISOR QUESTIONNAIRE

PART II: SCIENTIST/ENGINEER QUESTIONNAIRE

DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE OF TECHNOLOGY (AU)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

AUG 11 1976

REPLY TO ATTN OF: ENS/1Lt Koser/52549

SUBJECT: Survey Information

TO: Respondent
[redacted]

1. The attached questionnaire is Part I of a two-part survey, designed to provide information necessary for my masters degree thesis effort. Part I is to be completed by section chiefs and group leaders in the [redacted]

2. [redacted] has approved the administration of this questionnaire in [redacted] and made mention of it in his staff meeting and at the recent Commander's Call.

3. If you are a section chief or group leader, please complete the attached questionnaire, place it in the return envelope provided and mail as soon as possible. Let me emphasize that anonymity of all respondents will be maintained. The number in the lower left corner of the privacy statement is the approved survey control number and in no way identifies the questionnaire respondent.

4. Thank you for your cooperation and support in completing this thesis effort.

Michael C. Koser

Michael C. Koser, 1Lt, USAF
Graduate Student
Department of Systems Management
School of Engineering

Strength Through Knowledge

PART I: SUPERVISOR QUESTIONNAIRE

A. You are organizationally under: [redacted] (circle answer)

B. Length of time as supervisor of present section/group: ___yrs, ___mo

C. Listed below are types of output of the scientist/engineer in an R&D laboratory. If it is assumed that not all of these types of output are equal in importance to the [redacted], then each would carry a different weight as a measure of output. For example, two work unit planning documents may be equal to one proposal evaluation in importance. The proposal evaluation would be weighted twice that of a work unit planning document.

In the blank to the right of each of the following types of output, please fill in a weight which you feel best represents the relative importance of that type of output to the [redacted] The sum of these weights should equal 100.

1. Technical Report (including test reports) _____
2. Work Unit Planning Document _____
3. Journal Article (either submitted or published) _____
4. Procurement Package _____
5. Evaluation of Proposal _____
6. Computer Code _____
7. Technical Presentation(including those made outside the laboratory) _____
8. Management Presentation (budget review, for example) _____
9. Other (please specify) ________________ _____

Sum = 100

DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE OF TECHNOLOGY (AU)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

REPLY TO ATTN OF: ENS/1Lt Koser/52549 AUG . . 1976

SUBJECT: Survey Information

TO: Respondent
[redacted]

1. The attached questionnaire is Part II of a two-part survey, designed to provide information necessary for my masters degree thesis effort. Part II is to be completed by [redacted] scientists/engineers in non-supervisory positions.

2. [redacted] has approved the administration of this questionnaire in [redacted] and made mention of it in his staff meeting and at the recent Commander's Call.

3. If you are not a section chief or group leader, please complete the attached questionnaire, place in the return envelope provided and mail as soon as possible. Let me emphasize that anonymity of all respondents will be maintained. The number in the lower left corner of the privacy statement is the approved survey control number and in no way identifies the questionnaire respondent.

4. Thank you for your cooperation and support in completing this thesis effort.

Michael C. Koser

Michael C. Koser, 1Lt, USAF
Graduate Student
Department of System Management
School of Engineering

Strength Through Knowledge

PART II: SCIENTIST/ENGINEER QUESTIONNAIRE

A. Output Measures
During the past two(2) years, how many of each of the following have you authored, co-authored, prepared, presented, etc? (fill in the blank)

1. Technical Reports (including test reports) ______
2. Work Unit Planning Documents ______
3. Journal Articles (either submitted or published) ______
4. Procurement Packages ______
5. Evaluations of Proposals ______
6. Computer Codes ______
7. Technical Presentations (including those made outside the laboratory) ______
8. Management Presentations (budget review, for example) ______
9. Other (please specify) ______

B. Individual/Organizational Variables

a. Please complete the following:

Age ____ Current Grade/Rank _____

Education Level (circle highest degree) BS MS PhD Other(specify) _____

Time in current section/group: _____yrs, _____mos.

Length of time under current supervisor: ____yrs, _____mos.

Years of scientific/engineering experience(research, consulting, etc.) since first degree: _____

Nature of current work(% of time per category):

Research _____

Exploratory Development _____

Engineering Development _____

System Support _____

Contract Monitoring _____

Your frequency of communication (number per week) with:

Scientists/engineers within your section/group on technical matters. _____

Scientists/engineers outside your section/group on technical matters. _____

Supervisor on technical matters. _____

Your frequency of attendance at national or international professional society meetings (number per year). _____

You are organizationally under: [redacted] [redacted] (circle answer)

B. Please complete the following by placing an X above what you feel is the appropriate category. If you have been working for your current supervisor for less than six(6) months, answer these questions with respect to your previous supervisor.

1. Amount of pressure exerted upon yor by your supervisor for:

a. Quantity of output

1	2	3	4	5	6	7	8	9
No pressure-quantity of output never mentioned								Extensive pressure-quantity of output always stressed

b. Quality of output

1	2	3	4	5	6	7	8	9
No pressure-quality of output never mentioned								Extensive pressure-quality of output always stressed

c. Meeting deadlines and schedules

1	2	3	4	5	6	7	8	9
No pressure-deadlines/schedules never mentioned								Extensive pressure-deadlines/schedules always stressed

d. Relevancy of work to the Air Force mission

1	2	3	4	5	6	7	8	9
No pressure-relevancy of work to AF mission never mentioned								Extensive pressure-relevancy of work to AF mission always stressed

2. Extent of participation with supervisor on goal setting (including project selection) concerning your work

1	2	3	4	5	6	7	8	9
No participation-you set uour own goals or he sets them for you								Total participation-he always actively shares this function with you

3. Extent to which supervisor rewards:

a. Quantity of output

1	2	3	4	5	6	7	8	9

Never rewards quantity of output — Always provides meaningful rewards for quantity of output

b. Quality of output

1	2	3	4	5	6	7	8	9

Never rewards quality of output — Always provides meaningful rewards for quality of output

c. Innovative (new and useful) output

1	2	3	4	5	6	7	8	9

Never rewards innovative output — Always provides meaningful rewards for innovative output

4. How thoroughly does your supervisor evaluate your work?

1	2	3	4	5	6	7	8	9

No evaluation- he never evaluates your work — Total evaluation- he always evaluates your work in detail

5. Extent of control exerted by supervisor over your work

1	2	3	4	5	6	7	8	9

Absolute control- you have no freedom concerning your work — No control- you have total freedom concerning your work

6. Extent of supervisor's empathy (i.e., he understands your feelings)

1	2	3	4	5	6	7	8	9

No empathy- he never understands your feelings — Complete empathy- he always undertands your feelings

APPENDIX B

MEANS, STANDARD DEVIATIONS AND
CORRELATION MATRIX FOR
PREDICTOR VARIABLES

VARIABLE	MEAN	STANDARD DEVIATION
AGE	33.47	7.26
GRADE	3.02	.87
EDL	1.90	.72
TIMIS	3.20	3.02
TIMUS	1.39	1.16
YRSE	8.23	6.11
NATW	3.17	1.47
COMIS	3.51	2.31
COMOS	1.99	1.42
COMWS	1.81	1.31
FREQA	1.46	.58
ORGN	1.59	.49
QUANP	3.84	2.25
QUALP	4.87	2.50
TIMEP	5.51	2.31
MISSP	5.67	2.30
PART	5.27	2.80
QUANR	4.70	2.48
QUALR	5.45	2.33
INNOR	5.59	2.36
EVAL	5.55	2.21
CONTR	6.03	2.16
EMP	6.47	2.08

	AGE	GRADE	EDL	TIMIS	TIMUS	YRSE
AGE	1.0					
GRADE	.633**	1.0				
EDL	-.128	.086	1.0			
TIMIS	.323**	.285**	-.168	1.0		
TIMUS	.206*	.094	-.179*	.364**	1.0	
YRSE	.734**	.672**	-.028	.396**	.257**	1.0
NATW	.161	-.002	-.180*	.026	.161	.054
COMIS	.072	.106	.113	-.018	-.013	.208*
COMOS	.226**	.187*	-.128	.147	.118	.360**
COMWS	-.008	-.088	.060	-.022	.066	-.034
FREQA	-.028	.036	.289**	.010	-.106	.053
ORGN	.112	.108	-.241**	.083	.130	.128
QUANP	-.120	-.095	-.013	-.028	-.002	-.133
QUALP	-.143	-.176*	-.013	-.043	.032	-.223**
TIMEP	-.139	-.134	-.061	-.007	-.012	-.161
MISSP	-.162	-.114	.118	-.137	-.095	-.223**
PART	-.115	-.142	.048	-.176*	-.024	-.136
QUANR	-.121	-.047	.088	-.095	-.051	-.075
QUALR	-.098	-.042	.055	.021	.077	-.066
INNOR	-.120	-.072	.048	.015	.040	-.085
EVAL	-.157	-.096	-.015	-.127	-.018	-.164
CONTR	.026	-.088	-.117	-.078	-.022	.052
EMP	-.055	.002	.052	-.109	-.035	.059

* $p < .05$
** $p < .01$

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	NATW	COMIS	COMOS	COMWS	FREQA	ORGN
NATW	1.0					
COMIS	-.169	1.0				
COMOS	-.027	.481**	1.0			
COMWS	.047	.517**	.299**	1.0		
FREQA	-.278**	.120	-.037	.069	1.0	
ORGN	.011	-.017	.135	-.042	-.203*	1.0
QUANP	.088	.032	.019	.108	.103	-.225*
QUALP	.064	.083	.046	.203*	.054	-.114
TIMEP	.112	.074	.030	.160	-.019	-.121
MISSP	.063	.046	-.005	.129	.053	-.202*
PART	-.013	.136	.043	.303**	.092	-.094
QUANR	-.015	.074	.186*	.108	.156	-.205*
QUALR	.052	.096	.233**	.132	.140	-.073
INNOR	.027	.159	.195*	.171*	.162	-.128
EVAL	.060	.094	.110	.216*	.087	.057
CONTR	-.-13	.043	.130	-.043	.038	.165
EMP	.042	.034	.187*	.012	-.028	.072

* $p < .05$
** $p < .01$

	QUANP	QUALP	TIMEP	MISSP	PART	QUANR
QUANP	1.0					
QUALP	.642**	1.0				
TIMEP	.646**	.596**	1.0			
MISSP	.391**	.482**	.590**	1.0		
PART	.081	.348**	.178*	.303**	1.0	
QUANR	.322**	.207*	.116	.205*	.411**	1.0
QUALR	.079	.307**	.114	.298**	.506**	.753**
INNOR	.117	.348**	.174*	.286**	.505**	.729**
EVAL	.159	.362**	.265**	.340**	.470**	.522**
CONTR	-.371**	-.197*	-.326**	-.206*	.135	.036
EMP	-.257**	-.122	-.132	-.008	.316**	.296**

* $p < .05$
** $p < .01$

	QUALR	INNOR	EVAL	CONTR	EMP
QUALR	1.0				
INNOR	.915**	1.0			
EVAL	.706**	.723**	1.0		
CONTR	.163	.122	-.018	1.0	
EMP	.407**	.352**	.286**	.367**	1.0

* $p < .05$
** $p < .01$

APPENDIX G

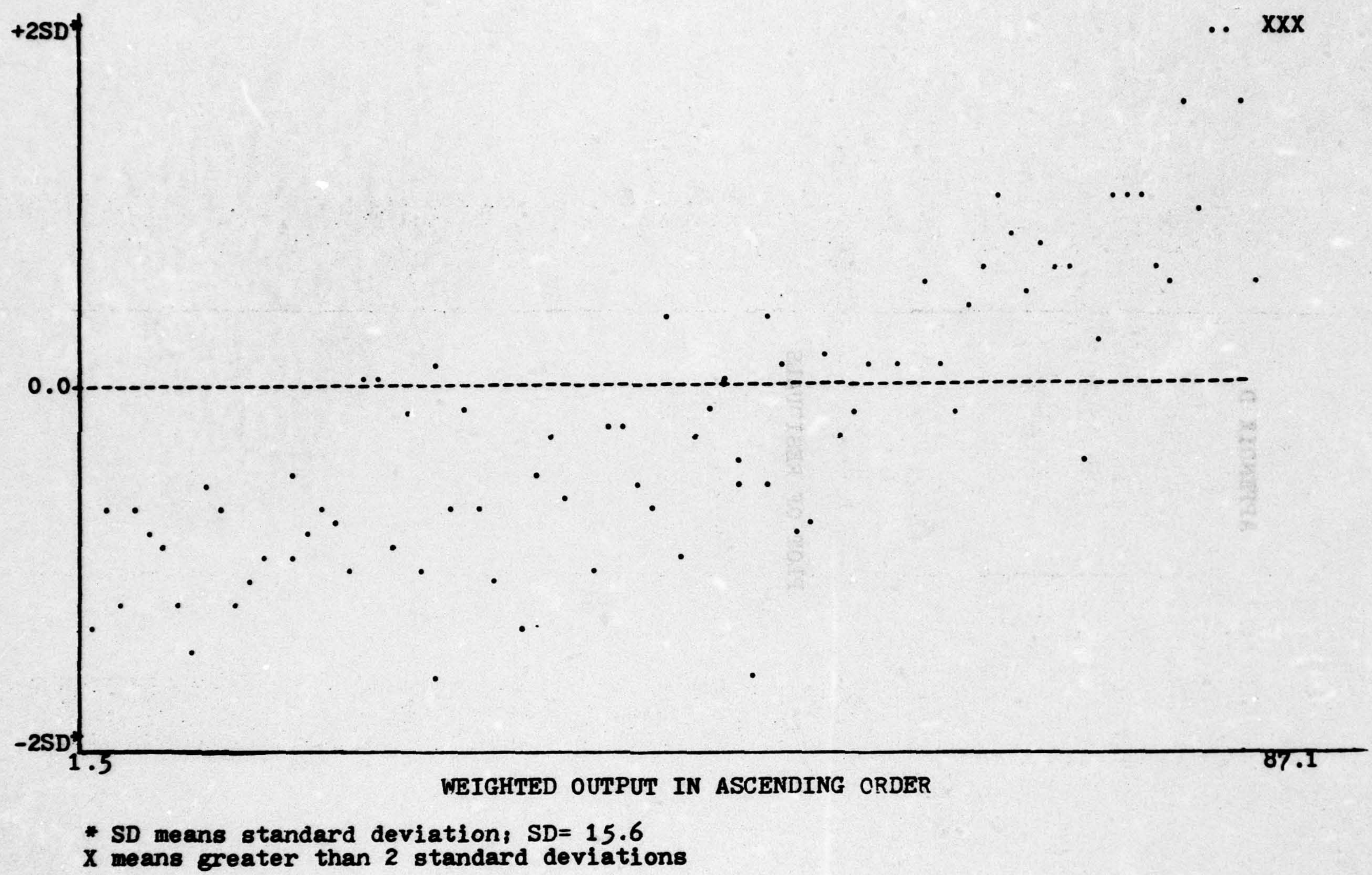
CODING SCHEMES

VARIABLE	VALUE	CODE
AGE	Age	Actual age
GRADE	Grade/Rank	(1)GS-7,8,9,NCO (2)Lieutenant (3)GS-10,11,12 Captain (4)GS-13,Major (5)GS-14, LtCol
EDL	Highest degree	(1)B.S. (2)M.S. (3)PhD
TIMIS	Number of years in section	Actual years
TIMUS	Number of years under supervisor	Actual years
YRSE	Number of years of experience	Actual years
NATW	Predominant nature of work	(1)Research (2)Exploratory development (3)Engineering development (4)System support (5)Contract monitoring
COMIS	Number of times per week	(1)0-3 (2)4-7 (3)8-11
COMOS	"	(4)12-15 (5)16-19 (6)20-23
COMWS	"	(7)24-27 (8)28-31 (9)32 or more
FREQA	Number per year	(1)0 (2)1-2 (3)3-4 (4)5-6 (5)More than 6
ORGN	Organizational membership	(1)Office A (2)Office B

VARIABLE	VALUE	CODE
QUANP	Scale value (1 to 9)	Actual Scale Value
QUALP	"	"
TIMEP	"	"
MISSP	"	"
PART	"	"
QUANR	"	"
QUALR	"	"
INNOR	"	"
EVAL	"	"
CONTR	"	"
EMP	"	"

APPENDIX D

PLOT OF RESIDUALS


+2SD*
0.0
-2SD*
XXX
1.5
87.1
WEIGHTED OUTPUT IN ASCENDING ORDER
* SD means standard deviation; SD= 15.6
X means greater than 2 standard deviations

Vita

Michael Curtis Koser was born on 28 April 1951 in Lancaster, Pennsylvania. He graduated from high school in Elizabethtown, Pennsylvania in 1969 and attended the United States Air Force Academy from which he received the degree of Bachelor of Science and a commission in the USAF in June, 1973. His first assignment was in the GBU-15 System Program Office, Eglin AFB, Florida, where he served as Data Management Officer until entering the School of Engineering, Air Force Institute of Technology, in September 1975.

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OUTPUT WEIGHTING

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Scientist/engineer productivity in a selected Air Force R and D laboratory was measured with the number of eight different types of output as reported by 135 scientists/engineers. A weighting scheme was developed from the results of a questionnaire administered to 53 first level supervisors in the laboratory. The correlation between the raw sum of the eight output types and the weighted sum was, r=.985. 23 predictor variables were compared to the reported output and seven were shown to be consistently associated with the

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20. reported productivity measures. Education level, frequency of attendance at professional society meetings, communication in and outside a scientist/engineer's section, participation in setting work goals and perceived rewards for quantity of output were positively associated with productivity. Length of time under the same supervisor was negatively associated with productivity. Canonical correlation analysis provided support for the existence of broad based types of output.